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Geotech/Materials Workshop –1984

Erosion Control for Road Design

March 19–22, 1984
Missoula, Montana

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Geotech/Materials Workshop,

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AGENDA
EROSION CONTROL FOR ROAD DESIGN
USDA Forest Service, Region 1

Holiday Inn
Highway 10 W. and Mullan Road
Missoula, Montana
March 19-22, 1984

INTRODUCTION

Date	Time	Topic	Speaker
Monday, March 19	1:00-1:15	Welcome	Beryl Johnston
	1:15-1:30	Objectives and Scope	Bob Hinshaw
	1:30-2:30	Effects of Erosion:	
		-Water Quality	Ron Russell
		-Fisheries	Paul Brouha
		-Road Construction and Maintenance	Mike Cook
	2:30-3:00	BREAK	

BASIC PRINCIPLES

Date	Time	Topic	Speaker
	3:00-4:30	Soil Erosion - nature and types, soil loss prediction, evaluation of soil loss reduction measures, and relation to mass movement.	Donald Gray
Tuesday, March 20	7:30-9:00	Role of Vegetation in the Stability and Protection of Slopes - hydro-mechanical influences of vegetation, root reinforcement, soil moisture depletion, slope buttressing and arching, surcharge from vegetation, effects of vegetation removal.	Donald Gray
	9:00-9:30	BREAK	
	9:30-10:30	Principles of Biotechnical Slope Protection - elements of system, role of vegetation, role of structures, compatibility between engineering and biological requirements.	Donald Gray

	10:30-11:30	Special treatments, Biotechnical Slope Protection - structure (low walls and revetments), quasi-vegetative techniques (fiber mesh, wattling, matting, sprigging), mechanical techniques (Check dams, serrated slopes, filters)	Donald Gray
	11:30-12:30	LUNCH	
	12:30-1:00	Special treatments (continued)	

<u>RESULTS OF CURRENT RESEARCH</u>

	1:00-2:00	Horse Creek Study - relationship between road construction and sediment production, effect of design standards and stabilization treatments.	Jack King
	2:00-2:30	BREAK	
	2:30-3:30	Silver Creek Study (Same topics as Horse Creek)	Walt Megahan
	3:30-4:30	Rain Simulator Studies pavement vs. unsurfaced roads, aggregate surfacing vs. unsurfaced, ditch treatments.	Ed Burroughs
Wednesday, March 21	7:30-8_30	Sediment Yield Prediction Model, R-1, R-4 Procedure - basis, availabality, limitations.	Walt Megahan

<u>DESIGN AND MITIGATION</u>

Wednesday, March 21	8:30-9:30	Principles of Road Design and Mitigation for Erosion Control on Forest Roads.	Walt Megahan
	9:30-10:00	BREAK	
	10:00-11:00	Available Data Base - land type inventory, soil surveys, identification of potential problem areas, Environmental Assessment Reports.	Herb Holdorf

	11:00-11:30	Vegetative Treatments - soil analysis, species selection, seeding mixtures and planting stock, site preparation, planting, fertilizing, mulching, after care.	Panel Al Martinson, Chairman Dale Wilson Leon Logan Dave Creighton
	11:30-12:30	LUNCH	
	12:30-2:00	Vegetative Treatments (continued)	
	2:00-2:30	BREAK	
	2:30-3:30	Erosion Control Practices of Montana Highway Department	Larry Ivanovitch
	3:30-4:00	National and Regional Road Design Guides and Standards.	Ted Zealley
	4:00-4:30	Idaho Best Management Practices.	Ted Zealley and Mike Cook
Thursday, March 22	7:30-9:00	Forest Road Design Guides and Practices - presentation by a representative from each Forest in attendance.	Forest Representatives
	9:00-9:20	BREAK	

POLICY AND WRAPUP

	9:20-9:40	Engineering Perspective	Beryl Johnston
	9:40-10:00	Regional Forester's Expectations	John Chansler

SPEAKERS

EROSION CONTROL FOR ROAD DESIGN

March 19 - 22, 1984

Name	Position	Organization	Location
Ed Burroughs	Res. Engineer	INT	Bozeman, MT
Paul Brouha	Fish. Prog. Mngr.	R-1, WL	Missoula, MT
John Chansler	Deputy RF	R-1	Missoula, MT
Mike Cook	Forest Engineer	Nezperce NF	Grangeville, ID
Dave Creighton	Private Contractor	Agro-Tech Co.	Kalispell, MT
Donald Gray	Prof. of Civil Eng.	U of MI	Ann Arbor, MI
Herb Holdorf	R-1 Soil Sci.	R-1 R&WS	Missoula, MT
Bob Hinshaw	R-1 Geotech. Eng.	R-1 E	Missoula, MT
Larry Ivanovitch	Agronomist	MT Hwy. Dept.	Helena, MT
Jack King	Res.Hydrologist	INT	Moscow, ID
Beryl Johnston	Director, E	R-1 E	Missoula, MT
Leon Logan	Hydrologist	R-1 R&WS	Missoula, MT
Al Martinson	Soil Sci.	Flathead NF	Kalispell, MT
Walt Megahan	Res.Hydrologist	INT	Boise, MT
Ron Russell	R-1 Hydrologist	R-1 R&WS	Missoula, MT
Dale Wilson	Soil Sci.	Clearwater NF	Orofino, ID
Ted Zealley	R-1 Preconst. Eng.	R-1 E	Missoula, MT

ROSTER

EROSION CONTROL FOR ROAD DESIGN
March 19 - 22, 1984

Forest	Name
Beaverhead	Gilbert Evans
	Andrew Hupe
Clearwater	Tom Brown
	Carl Johnson
	Gerald Knapp
	Richard Patten
Flathead	Stan Bones
	Linda Brandvold
	Craig Dewey
	John Ganiere
	Ken Hinzman
	Brad Russell
Gallatin	Tom Grabinski
	Alexander Morigeau
Helena	Larry Lewis
Idaho Panhandle	Don Bennett
	Bob Embry
	Tom Fea
	Jack Filipowski
	Dave McCarthy
	Jim Nieman
	Bill Salsig
Kootenai	Roy Grant
	Gordon Hanek
	Jim McBane
	Mike Remboldt
	Larry Tatum
	Chuck Williams
	Steve Wurz
	Rich Young
Lewis and Clark	George Cameron
Nezperce	Carol Greiner
	Richard Kennedy
Lolo	Roger Billadeau
	Richard Judge
	Mike Mitchell
	Joni Sasich
	Edward Skop
	Kirk Thompson
RO Engineering	Doug McClelland

SUPPLEMENTARY NOTES:

EROSION CONTROL FOR ROAD DESIGN

TRAINING COURSE E-1

PREPARED BY: Donald H. Gray
Professor of Civil Engr.
The Univ. of Michigan

CONTENTS:

SLOPE DEGRADATION

	SURFICIAL EROSION	MASS MOVEMENT
PROCESS:	Detachment & transport of individual particles	Movement of large soil masses along a discrete failure surface
PHYSICAL OR PREDICTIVE MODEL:	Universal Soil Loss Equation $A = R \cdot K \cdot LS \cdot C$	"Infinite Slope" or Circular Arc Analyses $F.S. = A \frac{\tan \phi'}{\tan \beta} + B \frac{c}{\gamma H}$
IMPORTANT SOIL PROPERTY:	Erodibility $K = f(D_{50}, C_u, \%org, texture)$	Shear strength $s = c + (\sigma - u) \tan \phi$
PROTECTIVE ROLE OF VEGETATION:	Interception Restraint Retardation Infiltration	Reinforcement Moisture Depletion Buttressing & Arching Surcharge
MOST EFFECTIVE VEGETATION:	<u>Herbaceous</u> Grasses & forbs w/dense root mats & good surface coverage by stems & foliage	<u>Woody</u> Shrubs & trees w/ strong vertical sinker & tap root system.

EROSION ON FOREST VS. AGRICULTURAL LAND

AGRICULTURAL LAND	FOREST LAND
• Flat... rain (& wind) most important sources of erosional energy	• Steep... gravity important source of erosional energy
• Surficial erosion most important degradational process	• Mass wasting most important degradational process
• Low infiltration rates... overland flow results frequently	• Generally quite permeable... overland flow rarely occurs
• Presents plane surface that is subject to sheet wash & rilling	• Presents uneven surface that quickly channels water into gullies
• Thick, well developed soil... erosion removes upper soil layers	• Thin, poorly developed soil... erosion removes soil & PM
• Low plant diversity, slower recovery (plant colonization) following disturbance.	• High plant diversity, more rapid colonization by pioneer plants after disturbance

PROTECTIVE ROLE OF VEGETATION
IN PREVENTING SURFICIAL EROSION

INTERCEPTION: Foliage and plant residues absorb rainfall energy and prevent soil compaction from raindrops.

RESTRAINT: Root system physically binds or restrains soil particles while above-ground portions filter sediment out of runoff.

RETARDATION: Stems and foliage increase surface roughness and slow velocity of runoff

INFILTRATION: Plants and their residues help maintain soil porosity and permeability.

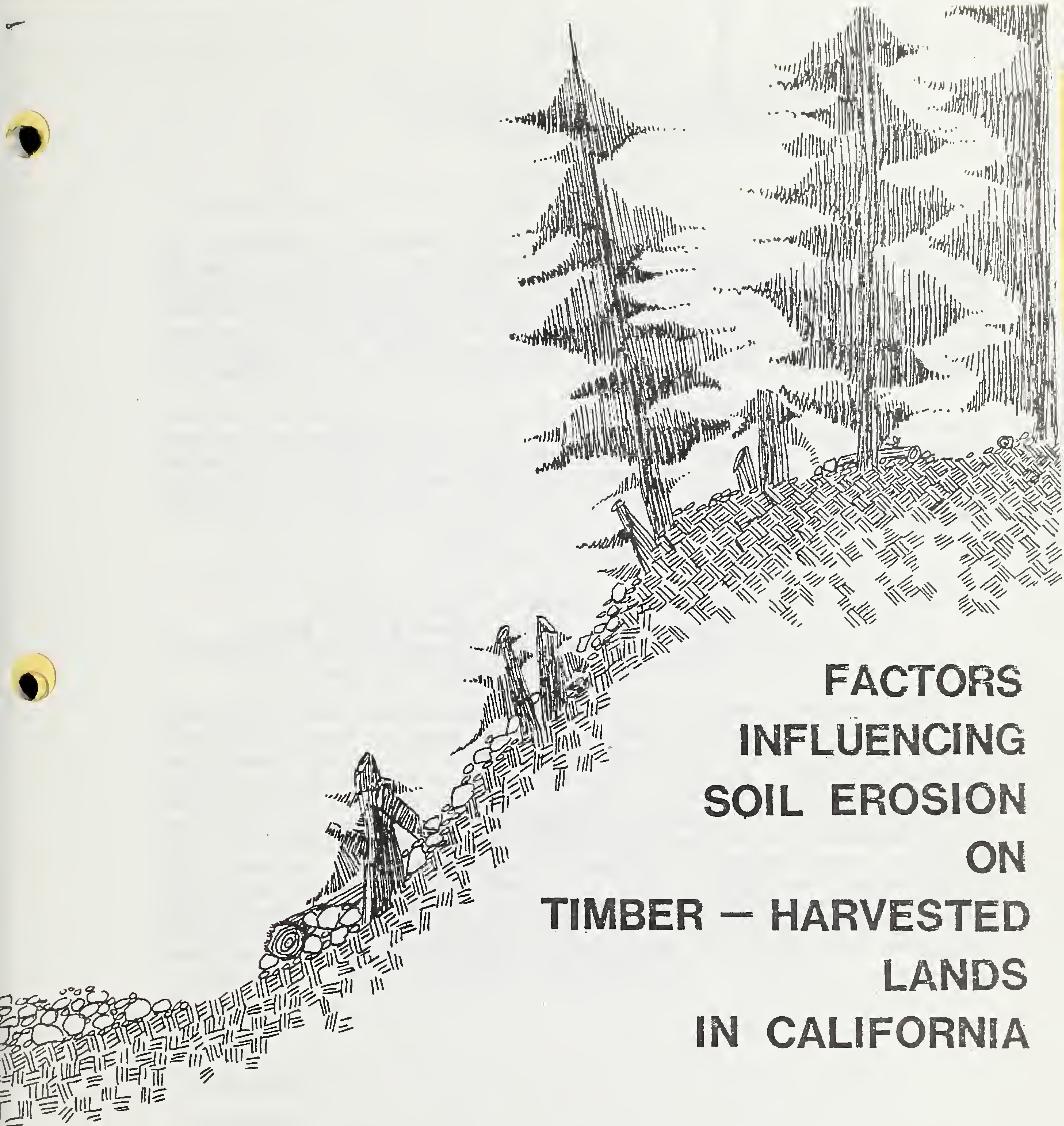
PROTECTIVE ROLE OF VEGETATION
IN PREVENTING MASS MOVEMENT

ROOT REINFORCEMENT: Roots mechanically reinforce a soil by transfer of shear stress in the soil to tensile resistance in the roots

SOIL MOISTURE DEPLETION: Evaporation-transpiration and interception in the foliage can limit buildup of soil moisture stress.

BUTTRESSING & ARCHING: Anchored and embedded stems can act as buttress piles or arch abutments in a slope to counteract shear stresses.

SURCHARGE: Weight of vegetation can increase stability via increased confining (normal) stress it provides across the failure surface.



FACTORS INFLUENCING SOIL EROSION ON TIMBER – HARVESTED LANDS IN CALIFORNIA

A Study for the California Department of Forestry

June 1983

WESCO WESTERN ECOLOGICAL SERVICES COMPANY

Abstract

Soil erosion and site variables were measured annually at 63 logging plots in California during the period 1976-1979. Over 80 percent of the measured soil erosion was produced by less than 15 percent of the plots. Mass wasting was the predominant erosional process and accounted for 77 percent of the measured erosion. Much of the measured erosion was associated with roads and landings; harvest areas generally experienced little erosion.

A number of regression models were developed using natural site characteristics, expressions of site disturbance, and timber harvest plan features in an attempt to explain various types of erosion, such as mass wasting. Several models were developed that explained over 70 percent of the variability in erosion. Among the best models were:

$$\ln(V37) = -2.8 + 16.4\,V8 - 0.07\,V25 + 0.02\,V4$$

Where: V 37 = Total mass movement (cubic yards).
V 8 = Average plot slope (sine of plot slope).
V 25 = Total surface area exposed on plot (percent).
V 4 = Mean annual precipitation (inches).

The analysis suggests that forest management and regulatory review would be more effective if it were to focus on those timber harvest sites which may experience major erosion events or "critical sites". Since the current Erosion Hazard Rating system does not adequately address mass wasting, a new critical site screening system is needed to identify these potential sites so that adequate pre-harvest planning can be accomplished. This analysis, together with other recent investigations, suggests the screening system should focus on harvest plan elements and land-form features. Additional guidelines and design elements for planning and constructing roads and landings may also be needed for sites identified as being potentially critical.

FIGURE 3-2

PIE DIAGRAM OF RELATIVE CONTRIBUTION
OF DIFFERENT TYPES OF EROSION
TO THE TOTAL EROSION

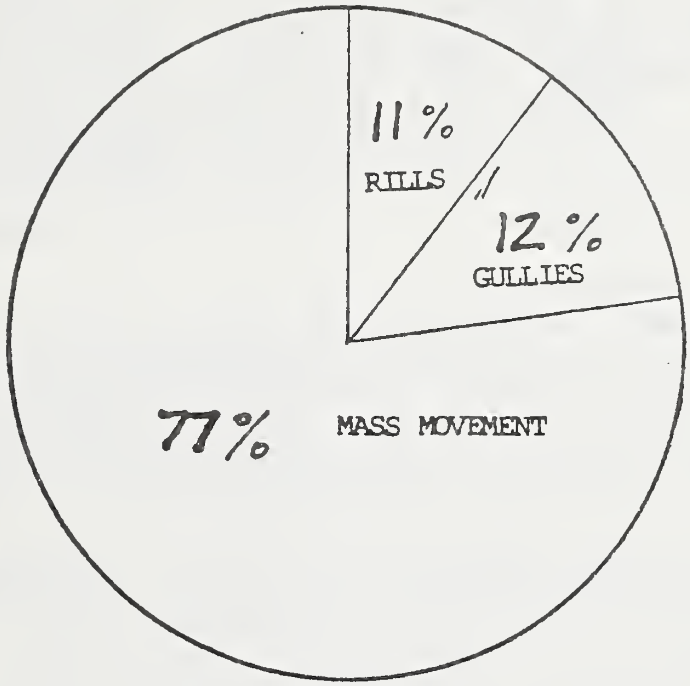


TABLE 3.1

VALIDATION OF DEPENDENT VARIABLES

Sources of Erosion	Types of Erosion: Mass Movement	Gully & Rill	Rills	Total Erosion
Roads				
Skid Trails	Erosion measured @ 63 sites			
Landings	over 3-yr period, 1976-'79			
Harvest Areas				
Plot Total Erosion				Grand Total Erosion

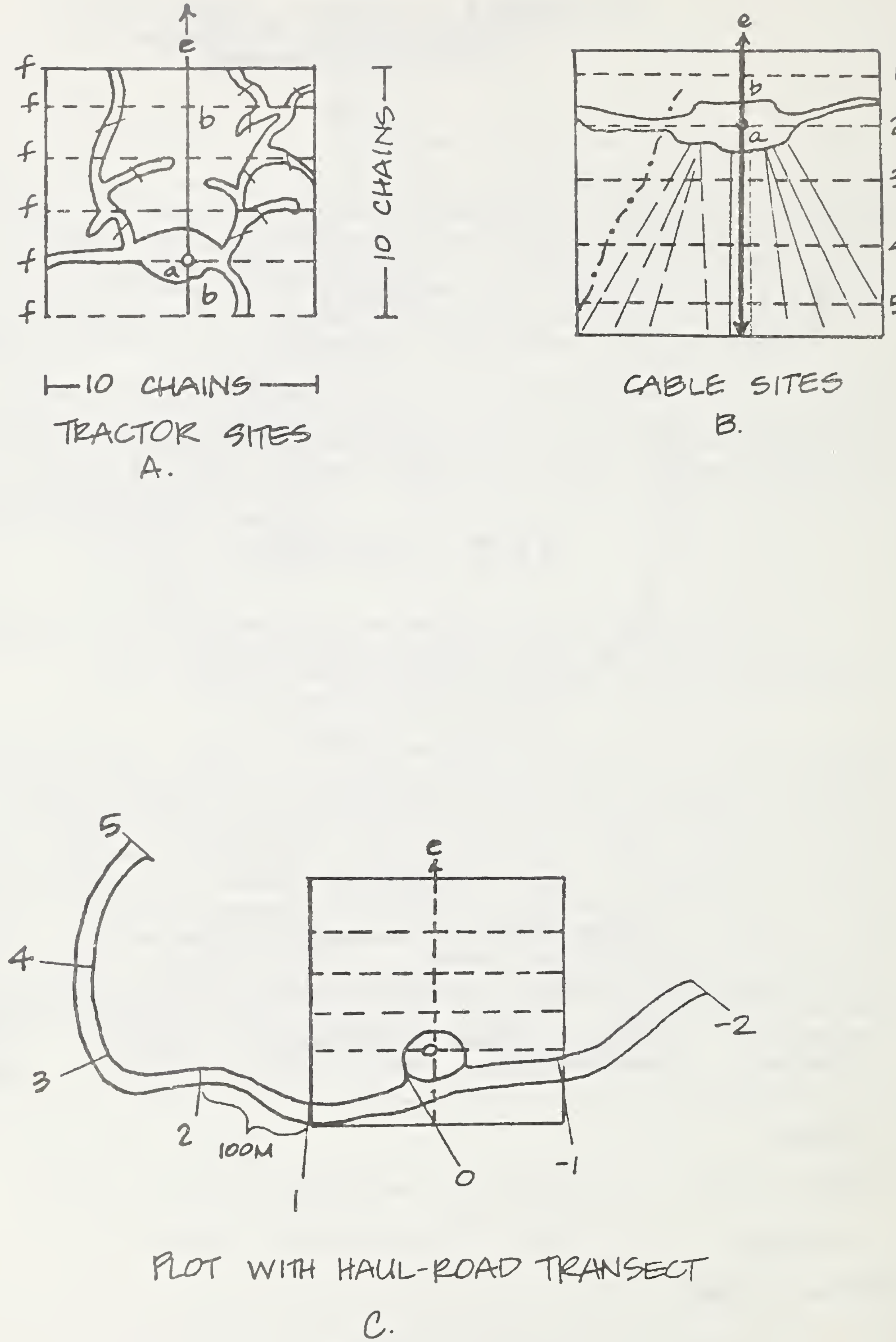


Figure 2-1

Plot Layout

4.0 CONCLUSIONS AND RECOMMENDATIONS

While data analysis from these studies is limited and has not clearly established the relationship between site characteristics, forest practices, and soil erosion, the information developed does provide some potentially useful insights which may help to direct forest management policy, as well as to guide subsequent erosion research. Tentative conclusions which can be reached, and are supported in part by other recent studies, are as follows:

4.1 Conclusions

- Soil erosion on timber harvested lands in California appears to be dominated by a relatively small percentage of harvest operations which yield a disproportionately high amount of the total erosion volume. Similar findings are reported by Rice and Datzman (1981) and McCashion and Rice (1983) for northwestern California.

- Mass movement incidents and large scale gullying are generally the dominant erosional processes (in terms of volume of soil moved) occurring on these extreme event, or critical sites. As in this study, Dodge et al. (1976) found in a previous investigation that the Erosion Hazard Rating System was inadequate for estimating the potential for mass movement.

- Although the data analysis from this study is incomplete, it appears that roads and landings are major sources of erosion on timber harvested lands, particularly when compared to erosion from harvest areas. Relatively low amounts of erosion from harvest areas were noted. Anderson, (1974), and Fredriksen, (1970), also cited forest roads as the chief contributor to sedimentation, relative to harvest areas.

- The California Department of Forestry Erosion Hazard Rating was not modeled directly in this study. The components used in determining a timber harvest site's EHR, when viewed compositively, (slope, geologic map unit, soil depth, soil texture, mean annual precipitation) were modeled and found to be only fair predictors of total soil erosion. Datzman, (1978) has also found the Coast District EHR to be a poor predictor of erosion. Slope, geologic map unit, and mean annual precipitation were found to have the highest degree of correlation in this study.

6.0 LITERATURE CITED

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2. CLASSIFICATION AND CAUSES OF SLOPE FAILURES

DHG 4/8/82

CLASSIFICATION & CAUSES OF SLOPE FAILURES

I. CLASSIFICATION

A. Materials

1. Ice
2. Rock (jointed, weathered, bedded, folded)
3. Soil (dry vs. saturated, sandy vs. clayey)

B. Velocity

1. Rapid (seconds → minutes)
   rockfalls, avalanches, earthflows, "air cushion" slides
2. Intermediate (minutes → hours)
   debris slides, block glides, slumps
3. Slow (days → years)
   creep, solifluction, lateral spreading

C. Displacement

Dist. mat'l. moves = f(max veloc, topography, size, entrainment of air & H_2O)

D. Failure Mechanism

1. Slides - Movement along well defined sliding or shearing surface of largely intact blocks or masses of earth and rock.

   a) Planar: Occurs in slopes where there is some geologic control, e.g., bedding planes, joints, colluvium mantle. Also shallow slides (sloughing) in homogeneous, sandy slopes (See Fig. 2.11)

   b) Rotational: Occurs in slopes composed of homogeneous cohesive soils in which resistance to sliding is independent of depth. Crit. sliding surf. tends to be an arc passing deeply under slope where shear resistance is lowest and shear stresses high. (See Fig. 2.12)

2. Flows - Quasi viscous flow in which difficult to detect a distinct sliding surface. Motion dies out with depth. Tends to occur in saturated soils (sands, silts, clays) with a high water content.

3. Falls - falling mass of material loses coherent contact with stable, unmoving base. Tends to occur in jointed, brittle rock forming steep slopes.

E. Classification System

See classification system (Fig. 2.10) by Varnes which classifies according to:

Type of Movement - falls, topples, slides (rotational vs. translational), spreads, flows

Type of Material - rock, soil (coarse vs. fine)

II. FACTORS CONTRIBUTING TO INSTABILITY OF EARTH SLOPES.

See subdivision of factors (Table 2.10) according to those that contribute to:

High Shear Stress and/or Low Shear Strength

Slopes fail when shear stress >, shear strength along a critical sliding surface.

III. IDENTIFICATION OF UNSTABLE SLOPES

Identification of unstable slopes on slopes with a high landslide potential can be made using certain topographic, vegetative, hydrologic, and geologic indicators (see Table 2.11).

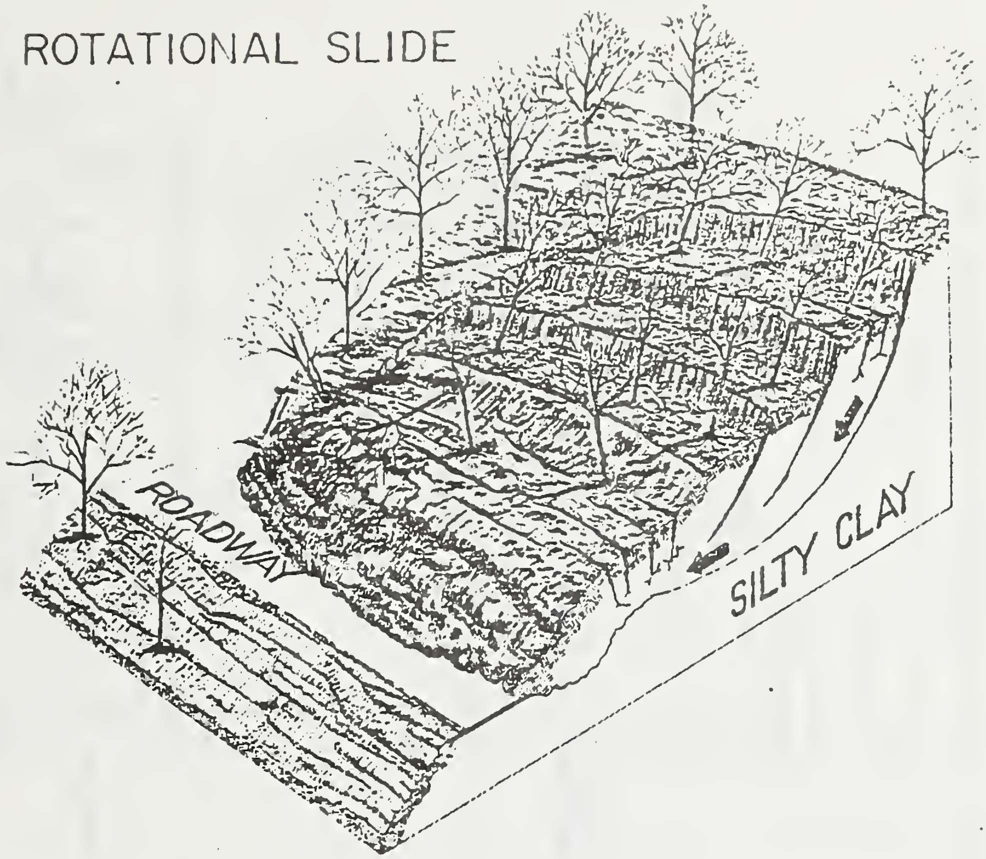


Figure 2.12. Schematic illustration of rotational, earth slump. (from Royster, 1978)

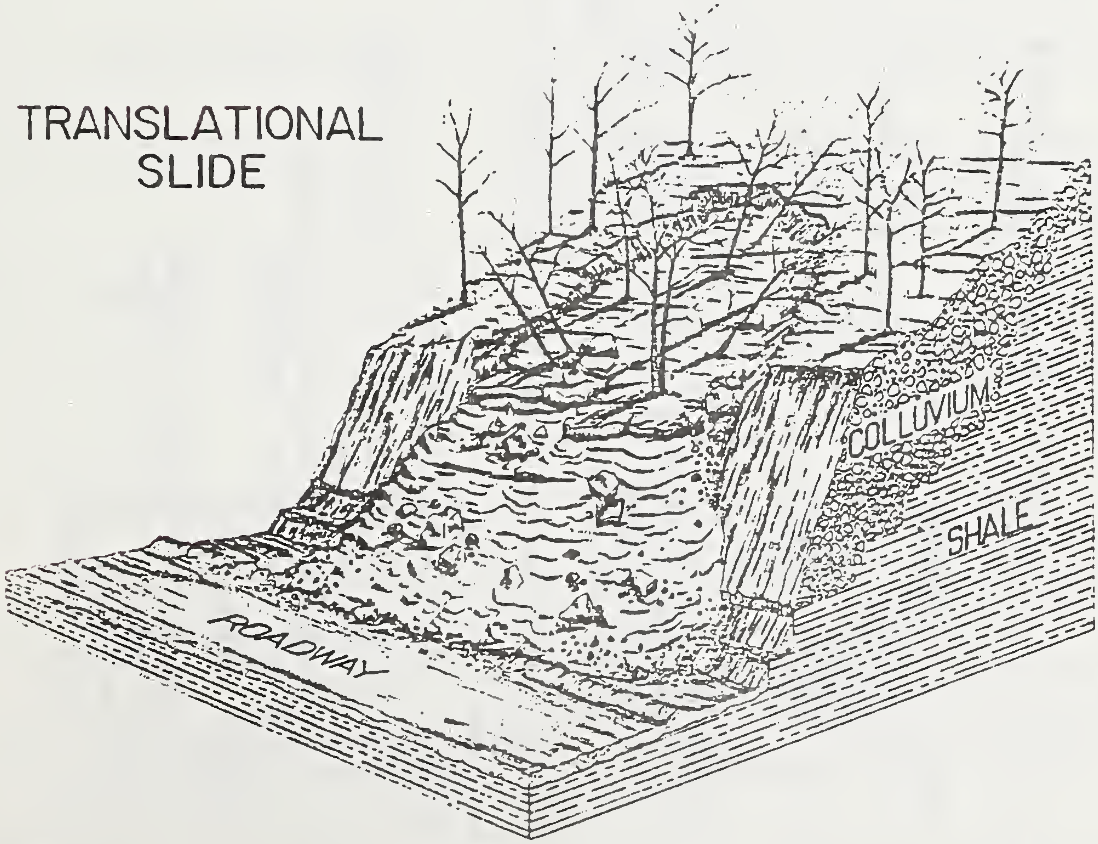


Figure 2.11. Schematic illustration of translational, debris slide(from Royster, 1978).

TABLE 2.10

FACTORS CONTRIBUTING TO INSTABILITY OF EARTH SLOPES

(After Varnes, 1958)

Factors that Contribute to High Shear Stress	Factors that Contribute to Low Shear Strength
A. Removal of Lateral Support 1. Erosion - bank cutting by streams and rivers 2. Human agencies - cuts, canals, pits, etc.	A. Initial State 1. Composition - inherently weak materials 2. Texture - loose soils, metastable grain structures 3. Gross structure - faults, jointing, bedding, planes, varving, etc.
B. Surcharge 1. Natural agencies - wt of snow, ice and rainwater 2. Human agencies, fills, buildings, etc.	B. Changes Due to Weathering and Other Physico-Chemical Reactions 1. Frost action and thermal expansion 2. Hydration of clay minerals 3. Drying and cracking 4. Leaching
C. Transitory Earth Stresses - earthquakes D. Regional Tilting E. Removal of Underlying Support 1. Subaerial weathering - solutioning by ground water 2. Subterranean erosion - piping 3. Human agencies - mining	C. Changes in Intergrannular Forces Due to Pore Water 1. Buoyancy in saturated state 2. Loss in capillary tension upon saturation 3. Seepage pressure of percolating ground water
F. Lateral Pressures 1. Water in vertical cracks 2. Freezing water in cracks 3. Swelling 4. Root wedging	D. Changes in Structure 1. Fissuring of preconsolidated clays due to release of lateral restraint 2. Grain structure collapse upon disturbance

TABLE 2.11 FEATURES INDICATING LANDSLIDES OR AREAS WITH HIGH LANDSLIDE POTENTIAL

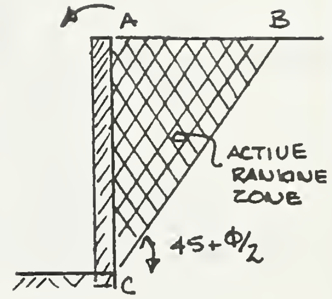
FEATURE	SIGNIFICANCE
1. Hummocky, dissected topography	Common feature in old and active progressive slides (slides with many individual components). Slide mass is prone to gullying.
2. Abrupt change in slope	May indicate either an old landslide area or a change in the erosion characteristics of underlying material. Portion with low slope angle is generally weaker and often has higher water content.
3. Scarps and cracks	Definite indication of an active or recently active landslide. Age of scarp can usually be estimated by the amount of vegetation established upon it. Width of cracks may be monitored to estimate relative rates of movement.
4. Grabens or "stair step" topography	Indication of progressive failure. Complex or nested series of rotational slides can also cause surface of slope to appear stepped or tiered.
5. Lobate slope forms	Indication of former earthflow or solifluction area.
6. Hillside ponds	Local catchments or depressions formed as result of (4) above act as infiltration source which can exarcerbate or accelerate landsliding.
7. Hillside seeps	Common in landslide masses. Area with high landslide potential. Can usually identify by associated presence of denser or phreatophyte vegetation (cattails, equisetum, alder, etc) in vicinity of seep.
8. Incongruent vegetation	Patches or areas of much younger or very different vegetation, e.g., alder thickets; may indicate recent landslides or unstable ground.
9. "Jackstrawed" trees	Leaning or canted trees on a slope are indicators of previous episodes of slope movement or soil creep.
10. Bedding planes and joints dipping downslope	Potential surface of sliding for translational slope movements.

SUMMARY OF LATERAL EARTH PRESSURES

I. FREE STANDING WALLS

A. COHESIONLESS BACKFILLS - ACTIVE PRESSURE $\quad s = \sigma \tan \phi$

1. Rankine Theory



Sufficient deformation occurs in backfill (i.e., by rotation or translation of a FRICTIONLESS wall) to produce a state of active, plastic equilib in a wedge of soil ABC behind the retaining wall.

Lateral earth pressure is reduced to a MINIMUM value consistent with equilib throughout the zone ABC (local equilib must be satisfied everywhere)

Case i) Horizontal Fill, Vertical Wall - P_A is HORIZONTAL

$$K_A = \tan^2(45 - \phi/2)$$

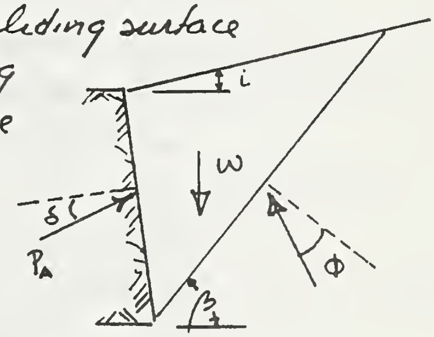
$$P_A = \tfrac{1}{2} K_A \gamma H^2$$

Case ii) Inclined Backfill - P_A inclined same angle (i) as backfill

$$\sigma_H = k \gamma z$$

$$\text{where } k = \cos^2 i \left[\frac{\cos i - \sqrt{\cos^2 i - \cos^2 \phi}}{\cos i + \sqrt{\cos^2 i - \cos^2 \phi}}\right]$$

2. Coulomb Theory

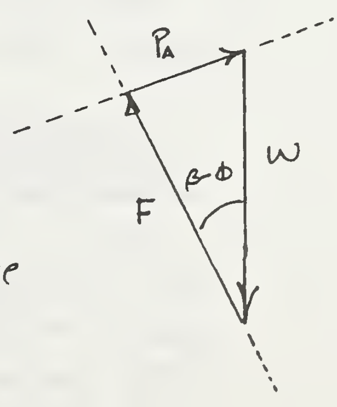


Assumes failure occurs along a PLANAR sliding surface rising from the heel of the wall and intersecting the backfill surface. Trial & error approach ... analyze forces acting on sliding wedge. Critical wedge is one that yields maximum thrust against wall.

a) Graphical solutions

I. Force polygons

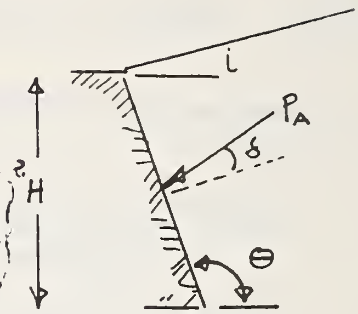
II. Engessor & Culman methods



No restrictions on angle of wall friction nor shape & inclination of backfill ($i \leq \phi$). Culman method especially useful for examining influence of line load on backfill.

b) Analytical solutions (based on "sliding wedge" analysis)

Case i) Sloping, planar backfill w/ battered wall & wall friction



$$P_A = \tfrac{1}{2}\gamma H^2 \left\{ \frac{\csc\theta \,\sin(\theta-\phi)}{\left[\sin(\theta+\delta)\right]^{1/2} + \left[\dfrac{\sin(\phi+\delta)\sin(\phi-i)}{\sin(\theta-i)}\right]^{1/2}} \right\}^2$$

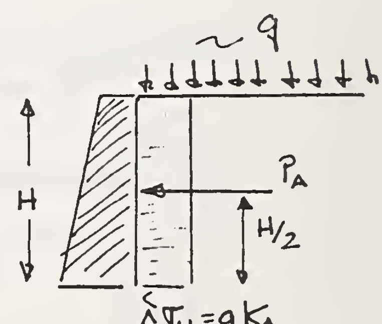
See also Fig. 13.22 in L & W for solns to above equation for special case where $\delta = 0$

Case ii) Vertical walls, horizontal backfill ($i=0, \theta=90°$)

.... see charts in L & W (Fig. 13-18) also T & P for $K_A = f(\delta, \phi)$

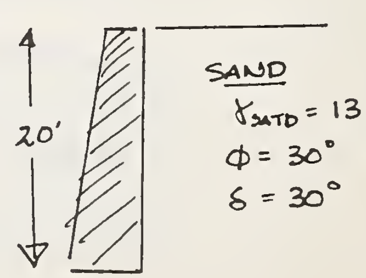
NOTE: Rankine & Coulomb theories give approx. same earth pressures in ACTIVE case regardless of δ (see Fig. 13-18); therefore, can generally use simpler Rankine theory ($\delta=0$) for active earth pressure calcs. Main effect of δ is to change direction of P_A

3. Influence of Surcharge and Water



- Surcharge (uniform) produces an additional stress distrib. against retaining wall equal to $\Delta\sigma_H = qK_A$. Resultant acts @ midpoint.
- Water in the back fill can have a profound effect on resultant force against wall. A perched GWT may inc. resultant 5X over dry backfill case. Essential to provide adequate drainage.

Condition	P_{AH} (lbs/ft)
submerged	3500
dry	5600
satd, slope drain	6,700
satd, vert. drain	8,800
satd, perched GWT	16,000

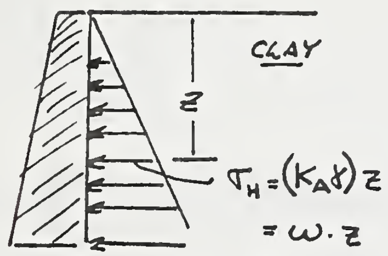


B. COHESIVE SOIL - ACTIVE PRESSURE $\quad s = c + \sigma \tan\phi$

1. C[illegible]ial Precautions

a) Avoid use of cohesive backfills whenever possible because actual behavior often completely at odds with theoretical predictions, e.g.,
- underestimate P_A & overestimate P_P as result of CREEP
- soil properties change w/ time & climate
- volume instability (swell & shrink) w/ $\Delta w/c$

b) If creep likely then use "EQUIVALENT FLUID PRESSURE" concept to est. lateral pressures, i.e. design wall to resist thrust of "heavy liquid"

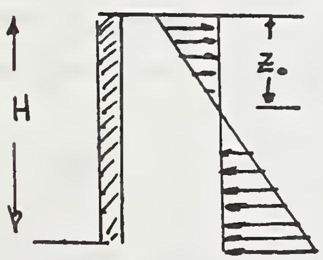


ω = equiv. fluid density

Backfill Matl.	ω (pcf)
dry sand	30
silty sand	35
clayey sand	45
sandy clay	55
silty clay	70
clay	85

c) Only use CLASSICAL theories if sure no changes in gross properties of soil w/ time & creep potential low.

2. Rankine Theory



Existence of cohesion implies a depth (region) where there are no compressive stresses against wall from the backfill, i.e.

$$\sigma_H = \sigma_A = \gamma z \tan^2(45 - \phi/2) - 2c\tan(45 - \tfrac{\phi}{2})$$

Depth (z_o) to which tensile forces act ($\sigma_H = 0$, $z = z_o$)

$$z_o = \frac{2c}{\gamma}\tan(45 + \phi/2)$$

Total thrust against wall

$$P_A = \tfrac{1}{2}\gamma H^2 \tan^2(45 - \phi/2) - 2cH\tan(45 - \tfrac{\phi}{2})$$

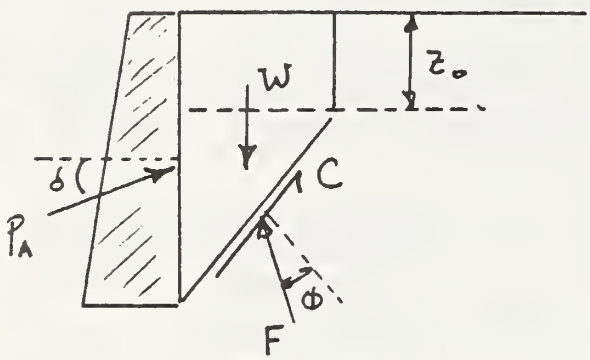
... purely cohesive backfill ($\phi = 0$)

$$P_A\big|_{\phi=0} = \tfrac{1}{2}\gamma H^2 - 2cH$$

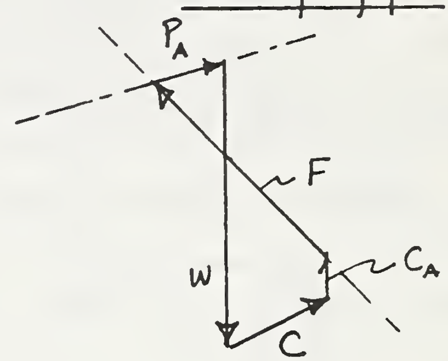
3. Coulomb Theory

Use graphical method or analysis of force polygon with following modifications

- Take into account cohesion along slip surface
- Neglect adhesion along the wall
- Assume discontinuity in sliding surface at depth z_o due to tension crack.



Force polygon:



4. Critical Height of Vertical Unsupported Cuts

Presence of cohesion in soil implies ability of soil to stand unsupported in a vertical cut or bank up to some critical height H_c. This critical height can be estimated by various theories... each of which makes certain assumptions about the stress boundary conditions or shape of the failure surface

OSSHA rules preclude reliance on any of these estimates although in many cases the predictions are accurate (e.g., height of loessial banks in hwy cuts)

	Theory	N_s
	Rankine	4.00
Kinematically Admissable	Upper Bound - Planar	4.00
	" " - Log Spiral	3.83
	Circular Arc	3.85
	[illegible] crack)	2.67
	Cycloid Arc	2.00
	Lower Bound (Static Equil)	2.00

$$H_c = \frac{N_s \cdot c}{\gamma} \tan\left(45 + \frac{\phi}{2}\right)$$

N_s = Stability No.

C. COHESIONLESS SOILS – PASSIVE PRESSURE

1. Rankine Theory

Some general comments under active stress apply... strains required to reach PASSIVE Rankine equilib are much higher. Lateral stress becomes MAJOR princ. stress

$$K_P = \tan^2(45 + \phi/2)$$ vert walls & horiz fill $\delta = 0$

2. Coulomb Theory

Planar slip surface only valid for $\delta < 1/3\ \phi$

If this condition is met, may analyze failure wedge by

a) Force polygons – trial & error

b) Engesser & Culman methods

3. Curved Failure Surface Analyses ($\delta \geq 1/3\ \phi$)

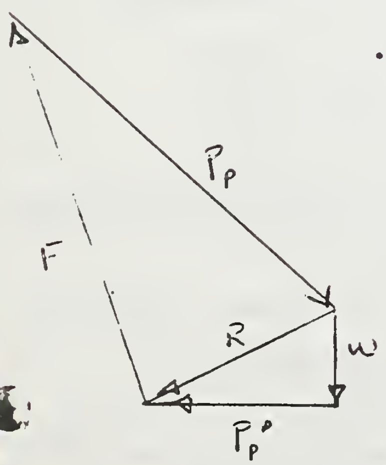
Case i) Horiz Backfill, Vert. Wall

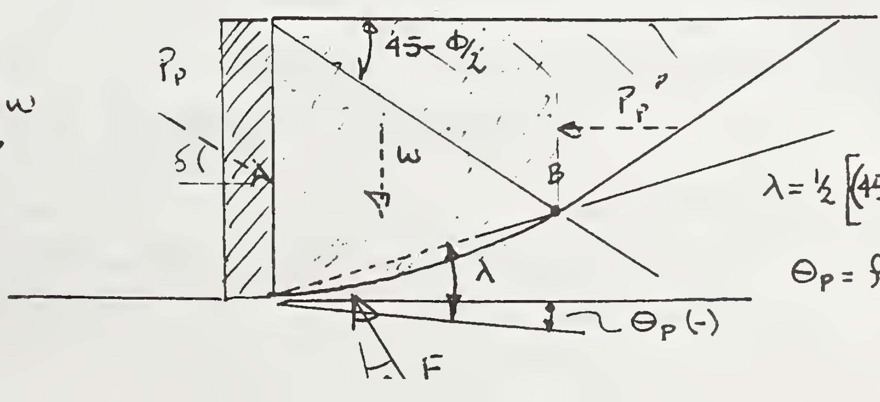
Use Fig. 13-20 in L&W to find $K_p = f(\delta, \phi)$

Note considerable influence of δ on K_p

Case ii) Irregular or Sloping Backfill,

- Use "trial & error" graphical method with circular arc or log spiral failure surface in backfill adjacent the wall.
- Method of Abdul-Baki may be used to locate critical failure surface (see Fig 7.07 c in P & M).





$$\lambda = 1/2\left[\left(45 - \frac{\phi}{2}\right) - \Theta_p\right]$$

$$\Theta_p = f(\phi, \delta)$$

III DESIGN REQUIREMENTS - GRAVITY RETAINING STRUCTURES

A. Types of Gravity Structures

1. Masonry & concrete walls
2. Crib & bin walls
3. Gabions
4. Cantilever & counterfort walls
5. Reinforced earth.

B. External Stability

1. Overturning: $\frac{R.M.}{Net\ O.M.} > 1.5$

2. Sliding: $\frac{N \tan \phi}{P_{AH}} > 1.5$ neglect P_p @ toe.

3. Bearing Force Location: $\frac{\bar{x}}{(B/3)} > 1.0$

4. Bearing Capacity: $\frac{q_{ULT}}{\sigma_{AV.\ BASE}} > 2.5$

C. Internal Stability

Structural members of wall must safely resist stresses placed upon them.

1. Cantilever wall - stem resist bending w/o cracking

2. Crib walls - "stretchers" & "headers" resist bending, torsional & compressive stresses from crib fill.

See Scharzoff (1975). Retng. wall practice for low-vol. forest roads. TRB Spec. Rept. # 160, pp. 128-140

4. Reinforced Earth
   a) Tie breaking
   b) Tie pullout.

III. REINFORCED EARTH® WALLS - METAL STRIPS

A. Elements of Reinforced Earth Structure

1. Fill

   To insure good frictional stress transfer to ties use only cohesionless, free draining mat'l.

   #200 mesh fraction ≤ 15%

   $\phi \geq 25°$

2. Skin (Facing)

   May be relatively thin & flexible... main function is to hold in backfill at face of wall. Little lateral stress transfer to skin

3. Reinforcement (Ties)

   Shear stresses which develop in backfill are transferred by friction to imbedded ties which react in tension. Important design criteria for ties are:

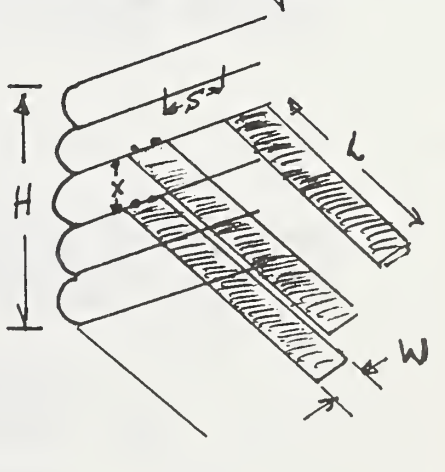
   a) Strong enough (large enough X section) to resist yielding or breaking in tension.

   b) "Frictional" enough (long and wide enough) to resist pullout.

B. Tie Design - Resistance to Tensile Breaking

1. Tie Back Wall Hypothesis

   (R) Method - Consider local equilib of wall area suppt. by one tie @ depth z



- Assume lateral stress incr. linearly w/depth
- Assume sufficient deformation in backfill to develop Active pressure conditions

$$\sigma_A = \gamma z K_A$$

$$(FS)_y = \frac{\sigma_y W t}{K_A \gamma H S X}$$

(CF) & (CM) methods give same FS provided

$n > 10$ $\quad$ n = no. ties

2. Coherent Gravity Wall Hypothesis

Reinforced earth backfill behaves as a coherent mass. Lateral earth stresses will be greater than those computed by Rankine tie back approach.

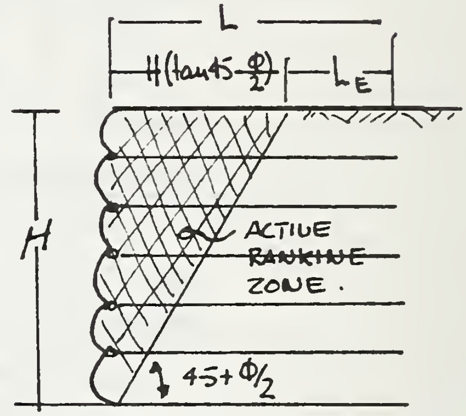
$$\sigma_A = \gamma z K (1 + K_A)$$

C. Tie Design - Resistance to Pullout

1. Tie Back Wall Hypothesis

Ⓡ Method (MOST CONSERVATIVE)

Postulates that ALL ties must extend a minimum length (L_E) beyond Rankine active zone



$$(FS)_\phi = \frac{2 L_E W \tan \phi_u}{S X K_A}$$

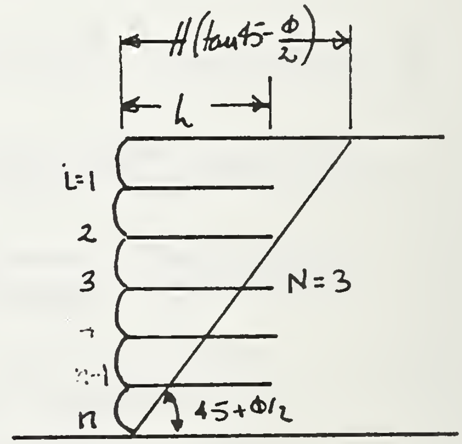
L_E = "effective" length

ϕ_u = angle of sliding or frictional resistance between tie & soil

$$L \geq L_E + H \tan(45 - \tfrac{\phi}{2})$$

Ⓒⓕ Method (LEAST CONSERVATIVE)

Considers overall stability of wall... not necessary that all ties extend beyond assumed sliding surface.



$$(FS)_\phi = \frac{4 X W \tan \phi_u}{K_A H^2 S} \sum_{i=N}^{n} i \left[L - (n-i) X \tan(45 - \tfrac{\phi}{2}) \right]$$

i = summation index for counting no. ties

N = value of i for first tie from top to extend past failure plane

n = no ties (in vertical tier).

(CF) Method (cont)

Iterative procedure:

#1. Set FS_ϕ' on LHS

#2. Estimate L ($L \approx 0.8H$)

#3. Calc N(L)

$$N = 17 - \frac{L}{X \tan(45 - \Phi/2)}$$

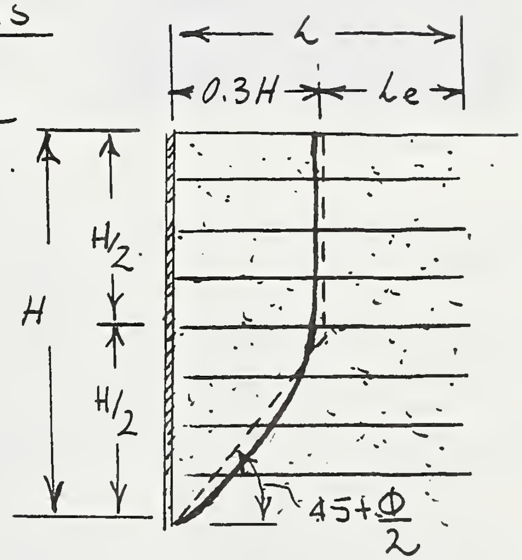
#4. Compute FS_Φ on RHS

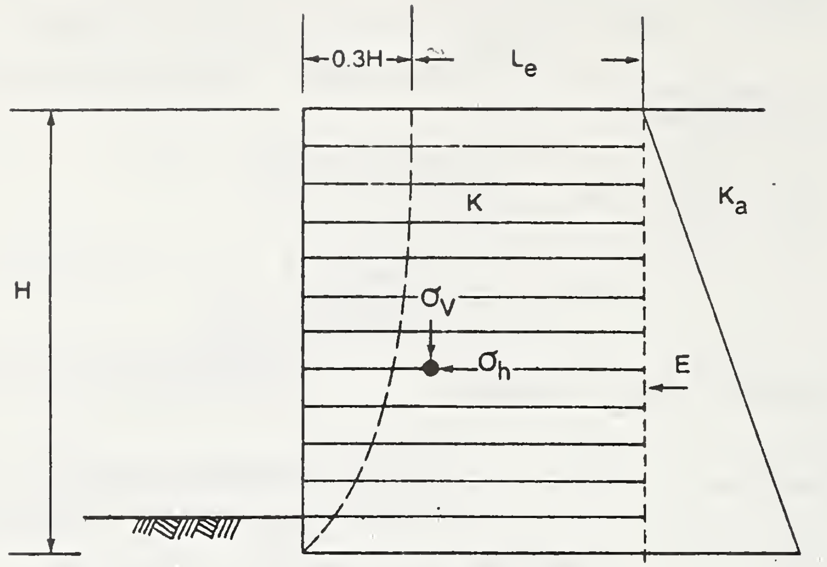
#5. Iterate... vary L until RHS = LHS

2. Coherent Gravity Wall Hypothesis

Failure surface is distorted (i.e. bent up) by presence of reinforce. The total length of tie is therefore reduced accordingly.

$$L \geq L_e + 0.3H$$



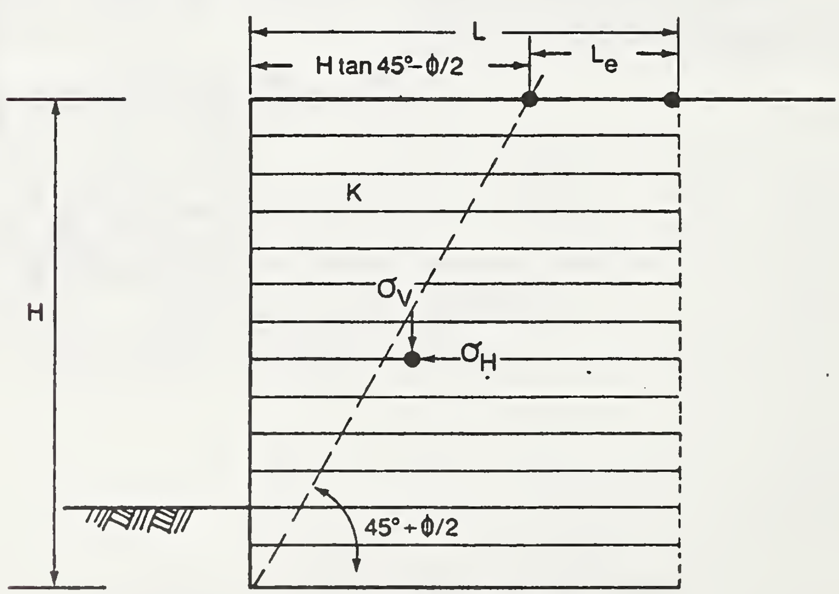


(a) Coherent Gravity Structure
Hypothesis

$\sigma_h = K(1 + K_a)\,\gamma H$

$L_e \leq L - 0.3H$ $L \geq L_E + 0.3H$

for $\phi = 30°$:
$\sigma_h = 1.33K \cdot \gamma H$



(b) Tie-Back Structure
Hypothesis

$\sigma_h = K \cdot \gamma H$

$L_e \leq L - H\tan(45° - \phi/2)$ $L \geq L_E + H\tan(45 - \phi/2)$

for $\phi = 30°$:
$L_e \leq L - 0.58H$

Design Hypotheses for Reinforced Earth Walls

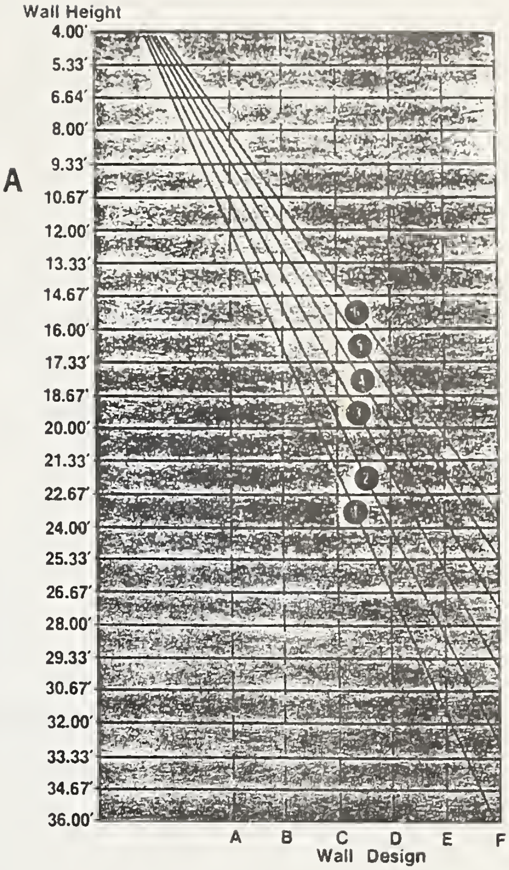
DESIGN OF GRAVITY TYPE RETAINING WALLS

Bin-Type Retaining Wall is a gravity retaining wall in which an earth mass inside bins acts as the gravity wall and the steel members hold the earth mass intact. These two components combine to resist overturning and sliding forces imposed by the retained soil and other superimposed loads. Because of this design, support for the wall is needed under the earth mass. On rigid foundations, provision must be made to allow slight settlement of the vertical corner members. Normal practice is to provide a compressible cushion under the base plates with approximately 8 inches of loose fill.

Individual walls should be designed for stability in accordance with established criteria for gravity walls. Recognized texts are available which thoroughly cover the design of gravity retaining walls, and these should be consulted by the engineer responsible for the design of the wall. Design Chart A, while no substitute for individual site design, presents long-used gravity wall criteria for width-to-height ratio under the typical loading conditions listed in Table I. However, they are presented here only as suggested guidelines.

A critical factor in wall design is the adequacy of the foundation. The resistance of the foundation to the overturning and sliding forces acting on the wall is a sophisticated engineering evaluation. *Proper site investigations and analyses should be carried out for any retaining wall.*

CHART A

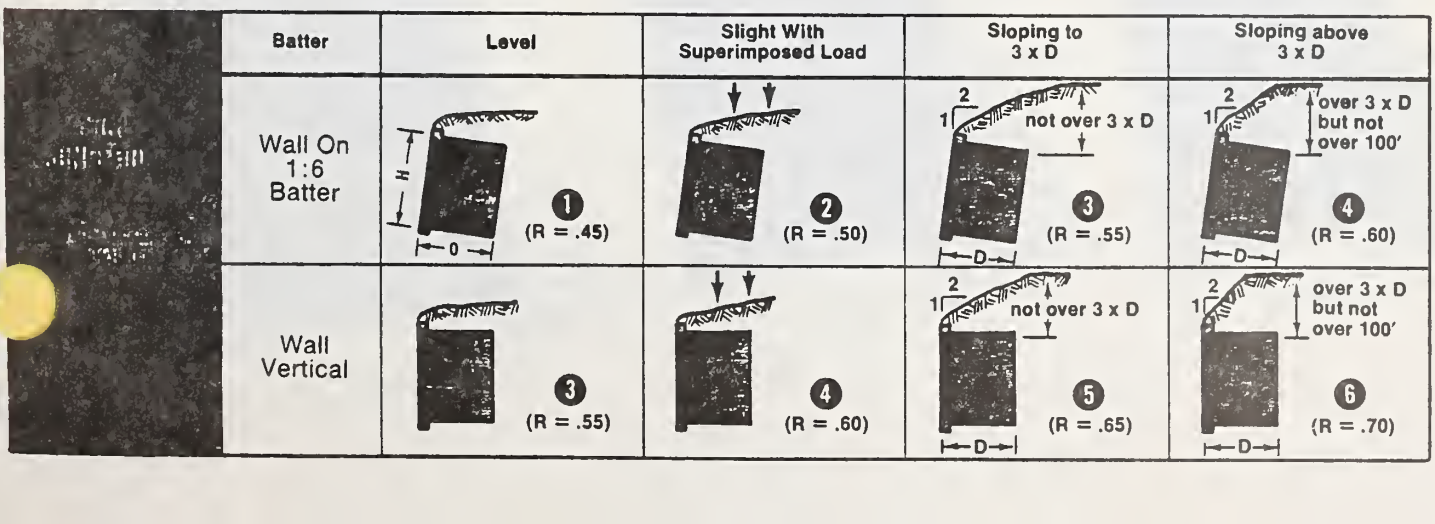


BATTER VS. VERTICAL. While batter walls should always be considered first, the advantages of vertical Bin-Walls, *where other considerations permit their use*, should not be overlooked. Careful analysis of a given situation will sometimes show a vertical wall of the same thickness as a batter wall will be structurally adequate. Even a thicker vertical wall will sometimes prove economical, land values considered.

Invariably, it is easier to construct a vertical Bin-Wall on a curve. Short stringers can be used in adjacent bins, for example, without restriction. If sharp bends are required, the special plates required are much simplified and more economical.

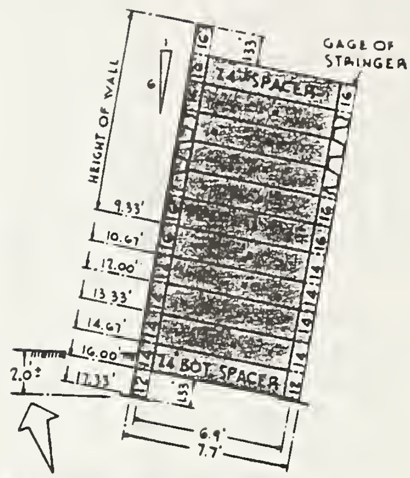
Under some circumstances, the obvious gain in usable space, by use of a vertical wall, will assume importance. For example, a vertical 24-foot-high wall will provide 4 square feet of valuable land for every foot of wall, as compared to a 1 to 6 batter wall with its toe in the same location.

It must be remembered that Armco Bin-Walls are flexible structures that will adjust to minor ground movements. To allow for this, as well as normal construction tolerances, vertical walls are frequently installed on a slight batter.



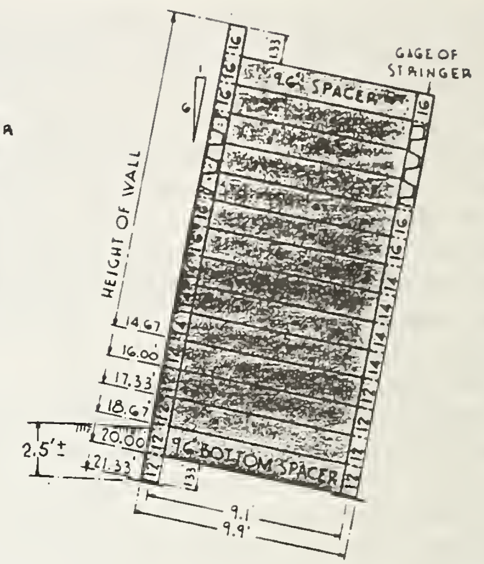
DESIGN A

DESIGN B

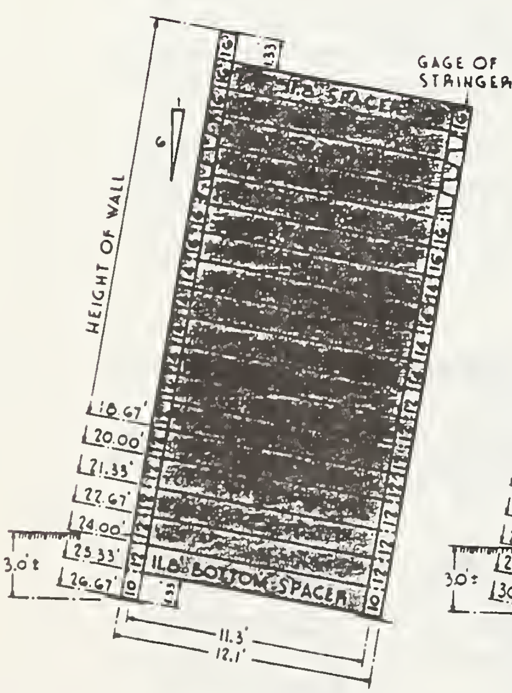


Note: These depths may vary to suit conditions

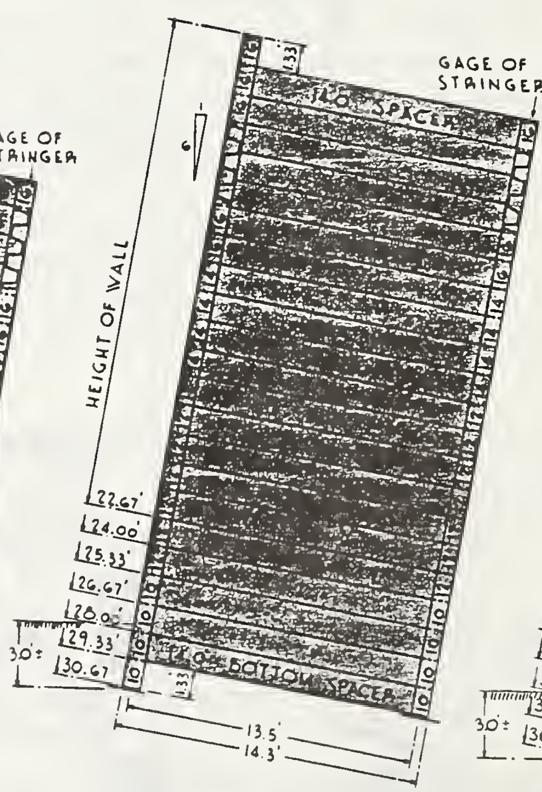
DESIGN C



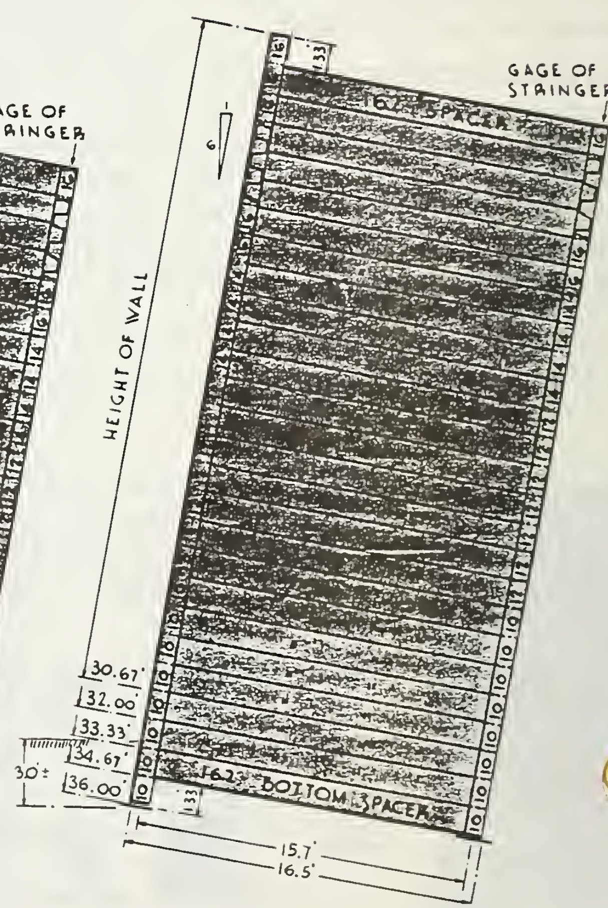
DESIGN D



DESIGN E



DESIGN F



TECHNICAL SPECIFICATIONS FOR
EROSION CONTROL MEASURES
AND
WATERSHED REHABILITATION

adapted from Tech. Specs.
for Watershed Rehabilitation,
Redwood National Park, U.S.
National Park Service, IFB
8480-0-02.

1980

INTRODUCTION

The attached set of technical specifications were developed for erosion control and watershed rehabilitation in Redwood National Park. The accompanying photographs were taken at rehabilitation test sites in the Park. The technical specifications are based on field trials and evaluations carried out over a two-year period from 1978 to 1980.

The specifications cover a range of both structural and vegetative treatments. All measures described are labor-skill intensive; they also emphasize the use of native, locally available materials.

The measures described herein can be applied in other watersheds where erosion problems have resulted from prior timber harvest operations. The specifications may have to be modified in a few instances to meet local conditions and requirements. In general, however, the attached specifications should provide a good basis for developing and implementing a watershed rehabilitation program.

TECHNICAL SPECIFICATIONS

I. CONTOUR TRENCHES

A. Definition of job.

A contour trench is a structural measure to control surface runoff and retard erosion. Contour trenches are discontinuous ditch-like structuresdug into the hillslope. They act as small reservoirs which catch surface runoff (and sediment in transport/ravel) before it has a chance to concentrate and develop rills and gullys on a hillslope. Runoff, generated during a storm, is stored in the trench until the post-storm period. During this period, water seeps through the trench into the soil. Unexcavated spaces between trenches on the same contour are an integral part of the trench. These spaces prevent excessive concentrations of water should a portion of a trench fail, and protects the remaining catch of a trench should only one segment fail. The storage capacity of a trench is eventually lost by slumping and sedimentation; however, it is hoped that both surface runoff will be sufficiently reduced, and the infiltration rate increased by established vegetation that the trenches will no longer be needed.

B. Job specifications. (see sketch, page 34)

1. Work shall progress from the top of the slope to be treated downward to prevent excessive compaction of trenches.

2. The grade for contour tenches shall be absolutely level. The grade shall be staked with Abney level, string level, or similar devices, and shall follow slope contour (i.e. horizontal trenches).

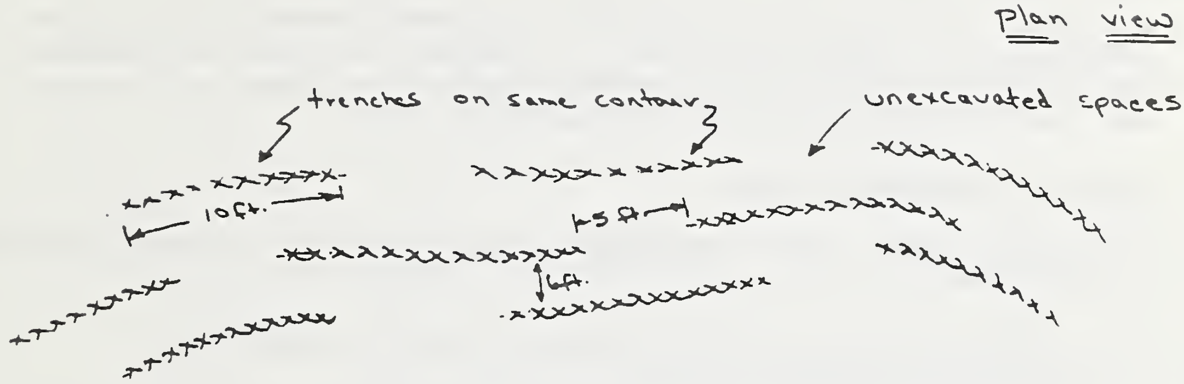
3. Contour trenches shall be 10 feet long and spaced 5 feet apart on the contour.

4. Spacing between rows of contour trenches shall be 6 feet (slope distance).

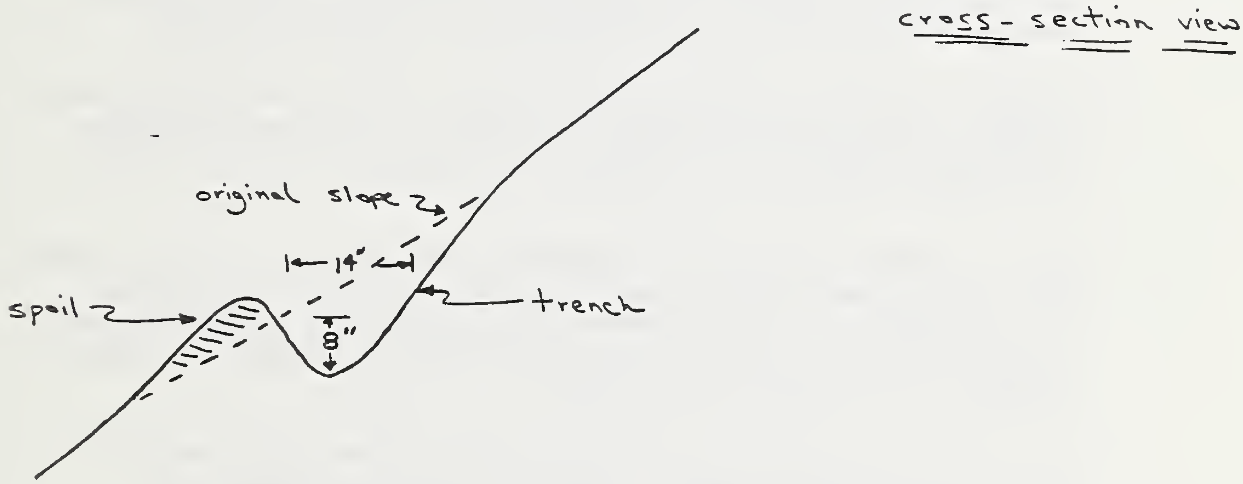
5. Trenches shall be excavated to a minimum depth of 8 inches and 14 inches across the top.

6. Trenches and unexcavated spaces shall be spaced in a staggered pattern.

CONTOUR TRENCHES: SCHEMATIC DRAWING



a. Staggered trenches and unexcavated spaces between successive contours.



b. Spoil from excavating contour trench placed to form downslope berm.

II. WOODED TERRACES

A. Definition of job.

A wooded terrace is a terrace constructed on a contour and supported by woody material. A wooded terrace is a structural measure which can retard surface erosion and hasten the establishment of vegetation.

B. Specifications of job.

1. Woody material is defined as limb, split product material, or bark.

2. S.O.W. shall specify spacing (slope or vertical) of wooded terrace rows.

3. The grade for wooded terraces shall be level. Stake out grade with an Abney level, string level, or similar device, and follow slope contours (i.e. horizontal terraces).

4. Cumulative diameter of woody material placed in a terrace shall be at least 8 inches. There is no maximum length for woody material; however, wood must contact the slope along its entire length.

5. Wooden stakes, driven vertically into the hillslope, shall anchor the wooded terraces. Stakes shall be greater than 1 1/4 inches in diameter and at least 24 inches long.

6. The maximum allowable spacing for stakes is 20 inches for woody material less than 40 inches in length; 30 inches for woody material greater than 40 inches in length. All ends of woody material must overlap stakes a minimum of 1 foot.

7. All stakes should be driven to a firm hold and at least 15 inches deep. Where soils are soft and 24 inch stakes are not solid, deeper stakes as necessary shall be used. Stake depths may be waived by the Contracting Officer or his/her representative on a site-specific basis at difficult sites where it is impossible to always meet minimum stake depths.

II.B.(cont'd)

8. Procedure for constructing multiple level wooded terraces:

   a. begin at bottom of slope to be terraced and work upward.

   b. stake grade of the first terrace.

   c. lay a row of woody material and drive stakes against the downhill side along the entire row.

   d. back fill and cover the row of woody material with clean soil found immediately upslope from the row until a flat terrace is formed. Tramp soil.

   e. repeat on next upslope level.

III. CHECK DAMS

A. Definition of job.

Check dams are constructed in gully and stream channels, and catch sediment in basins behind the dams. This sediment fill can stabilize the adjacent channel bank by preventing gully downcutting and lateral cutting if the runoff is directed through the spillway of the check dam and the dam is not undermined by channel downcutting from below the dam. The sediment fill behind the check dams and the raw soils on the adjacent channel banks (slopes) are planted heavily with cuttings after the check dams have been installed.

B. Composition of check dams.

Check dams can be constructed from on-site materials, such as split redwood boards from downed redwood logs on the site or on nearby logged areas, conifer boughs, rock, or other suitable material specified in the S.O.W. The choice of material will be determined by availability of the material at or near the site and the suitability of the material for the particular gully or stream. Based on limited past experience, in most sites the order of preference for check dam materials will be: (1) split or milled redwood boards, (2) rock, and (3) boughs. Design criteria for check dams may only be altered with written approval from the Contracting Officer, or his/her representative. In all other cases, the listed specifications shall be adhered to.

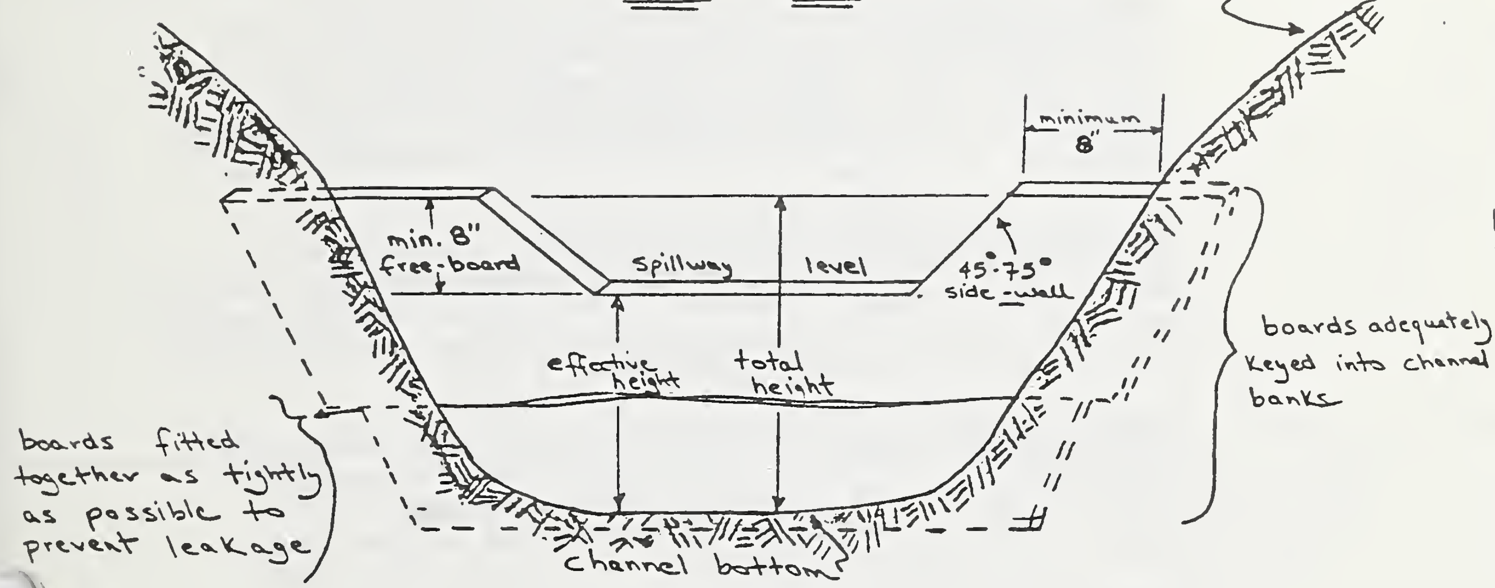
C. Split or milled redwood board check dams.

1. Thickness and length of check dams. Check dams shall be constructed of redwood boards long enough to span the entire width of the gully or stream channel and be keyed into the banks (see C8. below). Redwood boards shall be ≥ 1 inch thick. However, if dams exceed 6 feet in length, allowable thickness shall be at least 1 1/4 inches - 1 1/2 inches.

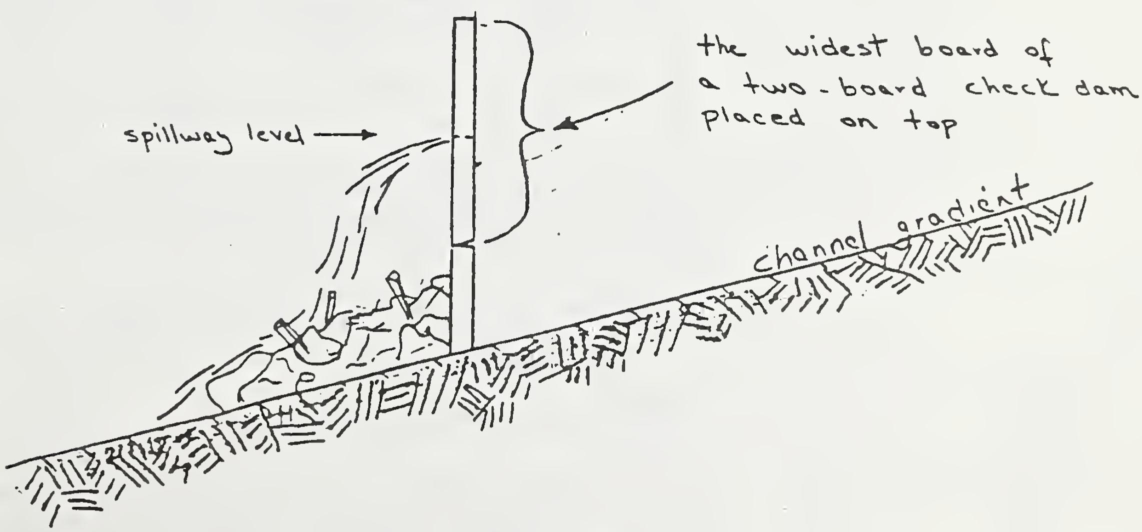
2. Free-board height. Check dam free-board height is the vertical distance between the spillway level and the lowest point of the top of the check dam (see sketch, page 38.) Free-board prevents high flows from cutting laterally into the channel banks and causing a check dam to fail. Free-board height shall be at least 8 inches.

Split redwood board check dam : schematic drawing

Front View



Side View



III.C.(cont'd)

3. Effective height. The effective height is the height of a check dam which actively traps and stores sediment (see sketch, page 38). It is the distance between the channel bottom and the top of the spillway. Effective height shall be at least 8 inches and maximized whenever possible.

4. Total height. Total check dam height is the sum of effective height and free-board height, and is dependent upon channel bank height. Generally, the higher the banks, the higher total check dam height can be. Maximum total check dam height shall be 40 inches.

5. Multiple redwood board check dams. Two redwood boards may be used in order to attain maximum total check dam height. However, the widest board shall be placed on top and shall never be cut through entirely inorder to construct a spillway.

6. Check dam spillway. Redwood board check dams must have adequate capacity spillways to accommodate high flows in the gully or stream channel. The S.O.W. shall specify the spillway area for check dams to be constructed in a reach of check dams.

7. Optimizing spillway design. Optimizing spillway design is important to the efficient placement and spacing of check dams in a channel. Spillway design shall proceed as follows (refer to sketch, p. 40):
   a. Based on channel configuration determine the maximum total check dam height.

   b. Place check dam perpendicular to channel and secure to channel.

   c. Measure an 8 inch free-board line onto dam (line C).

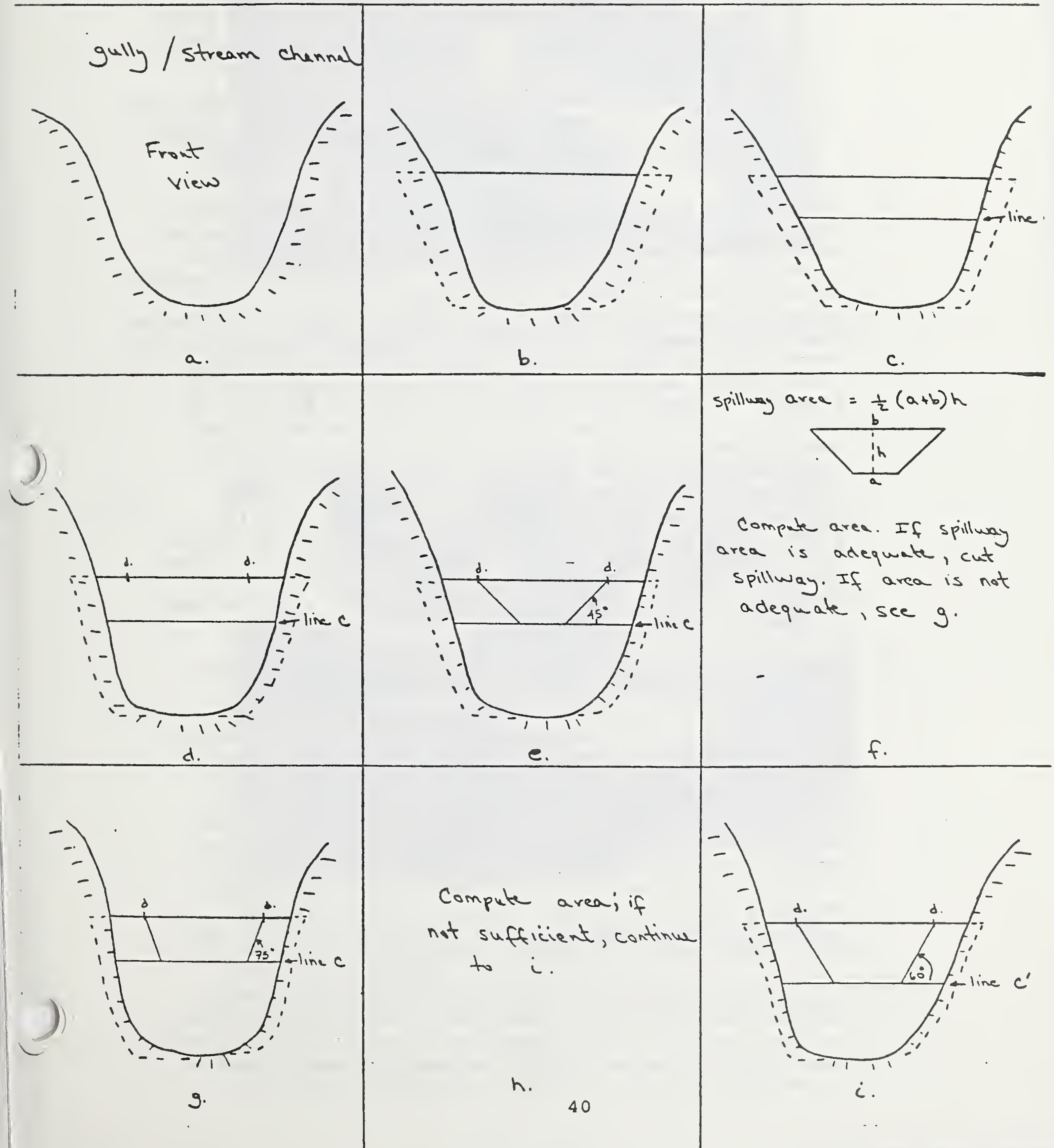
   d. Measure at least 8 inches from both banks where the check dam board enters the channel bank (points "d").

   e. Draw 45° to 75° side-walls from points "d" through line C.

   f. Compute the spillway area.

   g. If spillway area is less than the specified area, increase the spillway side-wall angle to a maximum of 75°.

Redwood board check dam: procedure to develop spillway capacity



h. Compute the spillway area.

i. If spillway area is still not adequate, lower the spillway level (line C') and vary side-wall angle to attain desired spillway area.

An important point to remember about spillway design is that a spillway shall never allow flow to impact upon channel banks at the base of a check dam.

8. Excavation into channel banks. Redwood boards shall be keyed into (inset into) channel banks to provide strength and prevent lateral breaching of the dam. Banks shall be neatly excavated (notched) only enough to inset the boards to a minimum depth of 6 inches. Excavate channel bottom to a minimum depth of 3 inches. The only exception shall be if channel bank excavation threatens to collapse the bank, or if the bank is composed of rock, or wood. If bank collapse is a problem, a compromise between enough excavation to prevent lateral breaching and a minimum amount of excavation to preserve the integrity of the bank shall be reached by on-site decisions with the Contracting Officer or his/her representative. Once a dam has been placed and inset into bank, clean fill material (i.e. fill containing no large rocks and/or woody debris) shall be packed into the channel bank where the dam is inset and along the upstream bottom of the dam. Clean fill must be used to seal the dam.

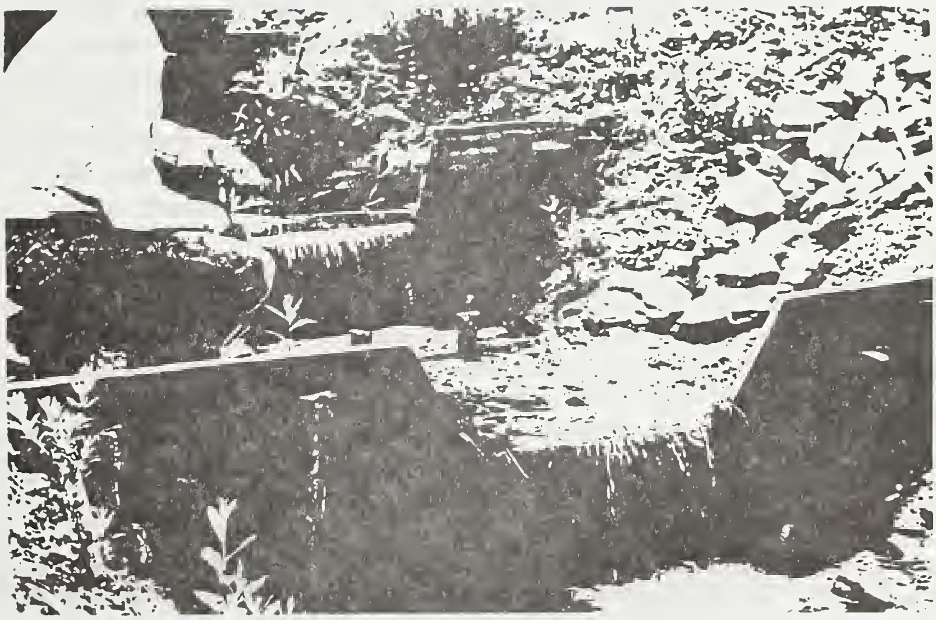
9. Anchoring redwood check dams. Check dams shall be securely anchored to the channel by either wood or metal rebar stakes. Both shall be driven at least 2 feet into the channel bottom and/or banks, and still have sufficient length to span at least 3/4 of the total check dam height. A minimum of 4 stakes shall be driven; two on each bank, with one against the upstream and one against the downstream side of the dam. Stakes shall contact the surface of the check dam and shall not interfere with flow through the spillway. When check dams exceed 6 feet in length, two additional stakes shall be driven against the downstream side of the dam evenly spaced across its length.

10. Energy dissipation. All redwood board dams must have adequate energy dissipation devices installed in the channel bottom immediately below the spillway. The energy dissipation can consist of rock, conifer or hardwood boughs, small woody slash, split or

check dams w/ rock energy dissipation

poles are willow stem cuttings

Split redwood board check dams with rock energy dissipators. Boards are keyed and staked into channel.



Milled redwood board check dams with trapezoidal spill_way design. Note willow stem cuttings which have rooted and sprouted.

milled redwood boards or a combi-ation of the above. Dissipators shall be: (1) firmly secured to the channel bottom, (2) located immediately below the spillway, and (3) as wide as the widest portion of the spillway notch. There should be no gap between the check dam boards and dissipators. Energy dissipartors must extend continuously downstream at least 1 1/2 times the effective height of the check dam.

D. Rock check dams.

1. Size of rock. The largest rocks which can be transported manually and which are available from a nearby locality shall be used to build up the dams. Smaller rocks shall also be used in the rock dam so that as many large holes as possible are filled in to reduce porosity.

2. Rock dam height. Rock dams shall be between 12 and 36 inches high.

3. Spillway. Rock dams shall be built with an adequate spillway notch as least five inches deep and five inches wide. Most importantly, the height of the rock dam shall increase from the spillway toward the gully bank so that all flow is channeled through the spillway region. It is recognized that spillway notches will be highly irregular and variable because of varying rock sizes.

4. Excavation into gully banks and gully bottom. Side banks shall be excavated at least 4 inches unless the ground is too rocky, or unless excavation threatens to collapse the bank. Gully bottoms shall be excavated at least 3 inches. These specifications may be altered by the Contracting Officer or his/her representative on a site-specific basis.

5. Energy dissipation. The slope of the rock dam on the downstream side generally provides adequate energy dissipation below the spillway. The downstream side of the rock dam shall not be so steep as to allow the free fall of water from the spillway notch onto the gully bottom; i.e., the rock dam shall also serve as an energy dissipator.

6. Anchoring rock check dams in place with wire mesh. All rock check dams shall be anchored securely in place using corrosion-resistant wire mesh. The wire mesh shall cover the rock dam, be fastened together with baling wire, and be secured to the gully bottom and side with wooden stakes or metal rebar. The entire rock dam, including the base, may also be enclosed in wire mesh, thereby forming an irregular shaped gabion. The wire mesh shall in all cases be securely anchored to the banks.

E. Bough dams.

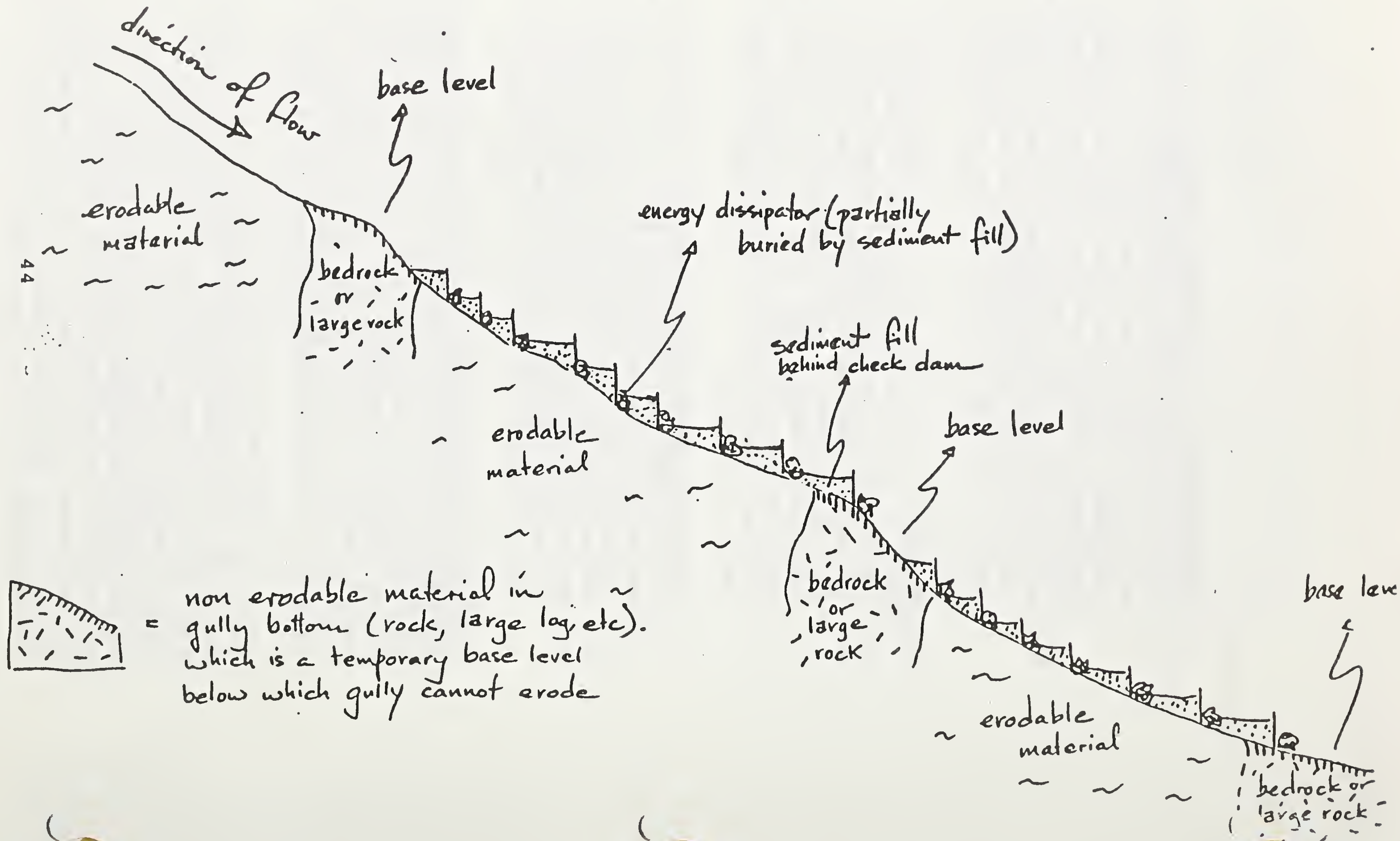
1. Utilization of bough dams. Bough dams can be an effective type of check dam in certain localities. No specifications for bough dams are given; however, the use of bough dams in a gully or stream reach shall be discussed with, and approved by, the Contracting Officer in writing prior to any bough dam installation.

2. Anchoring bough dams to gully. Because bough dams totally lose their leaves as quickly as 4 months after being cut and installed in gullies, it is important that the boughs be bound tightly together and staked firmly in the ground so that the bough dam does not become loose after the leaves fall. Rocky gullies that do not allow adequate staking are generally unsuited for bough dams.

F. Proper placement of check dams in a gully or stream channel. (see sketch, page 44) All check dams shall be placed properly in a gully or stream channel, otherwise downcutting will continue and will undermine the dams. Check dams shall be installed as integrated units, each of which acts to stabilize neighboring dams. Check dams shall be aligned perpendicular to the channel. This will prevent concentrating flow at either bank.

Dam construction shall begin from the bottom of a gully or stream reach to be checkdammed, and must begin at a "stable" point. Ideally, the lowermost check dam should be constructed on a non-erodable material such as bedrock, large boulders which the gully or stream cannot transport, or large logs partially buried in the gully or stream bottom. All check dams constructed upstream from the lowermost dam shall be placed so that the sediment fill behind the downstream dam (after it fills to the spillway level) abuts against the base of the upstream check dam (see sketch, page 44 .) To assure

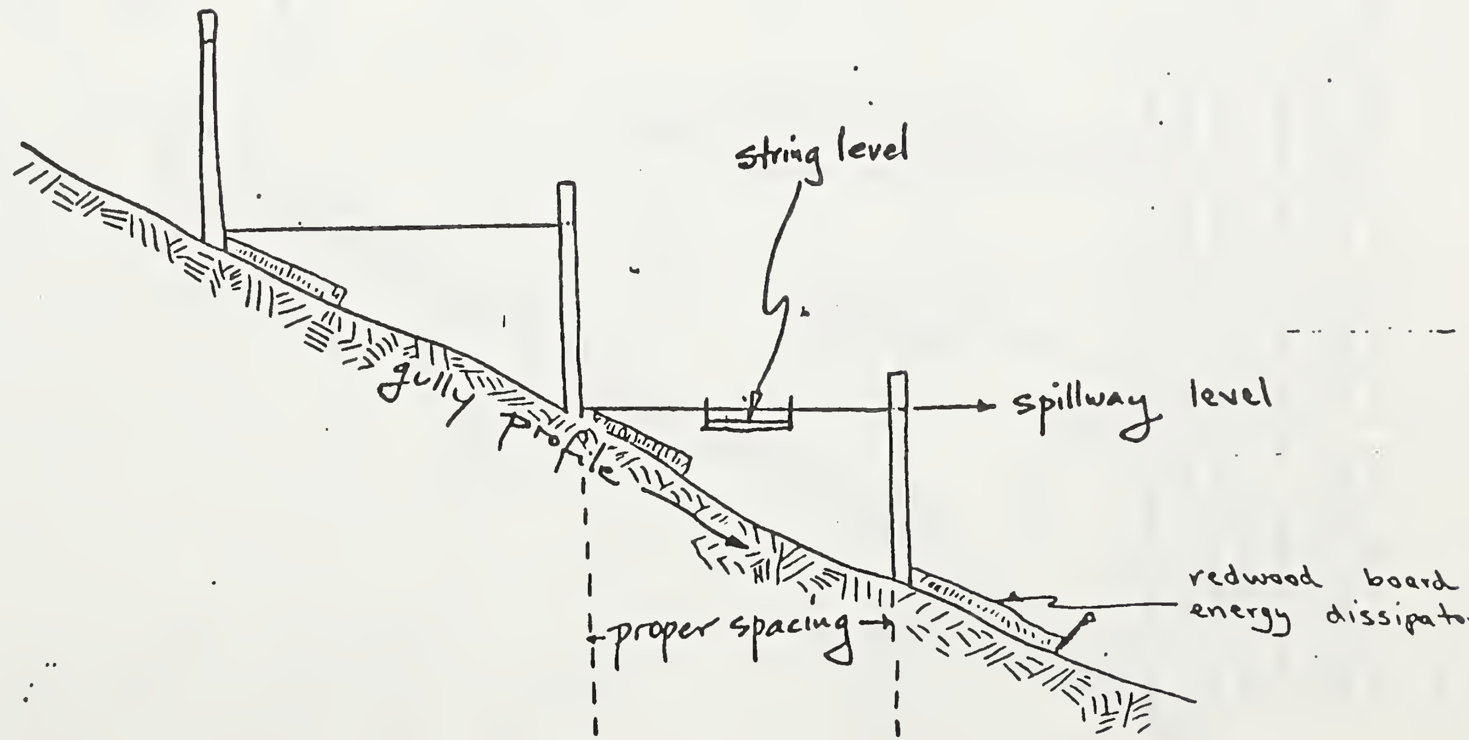
Profile along a gully bottom showing proper placement of two sets of check dams with lowermost check dam built on a non-erodable base (called a base level).



III.F.(cont'd)

this condition is met, use a line level to place upstream dams. Stretch a level line from the spillway level until it contacts the channel bottom upstream (see sketch, page 46). This point of contact denotes the location of the next upstream check dam. Construct that check dam and continue this process up the gully or stream reach to be checkdammed. A check dam's spillway shall be constructed before the next upstream check dam is placed.

Use of line level (string level) to determine proper spacing between check dams:



Former culvert and fill stream crossing. Fill has been removed and banks graded and seeded. Stream has subseqently downcut and undermined banks because channel was not protected.

Stream channel in former fill and culvert crossing which is protected by check dams and willow cuttings. This protection has eliminated stream downcutting and erosion.

IV. SUBMERGED SPILLWAYS

A. Definition of job.

A submerged spillway is nothing more than a submerged check dam placed with the spillway at streambed level. Like check dams, they can stabilize the adjacent channel bank by preventing downcutting and lateral cutting if runoff is directed through the spillway, and the submerged spillway is not undermined by channel downcutting from below the structure. Submerged spillway construction is most applicable in broad channels with shallow, poorly defined channel banks.

B. Specifications of job.

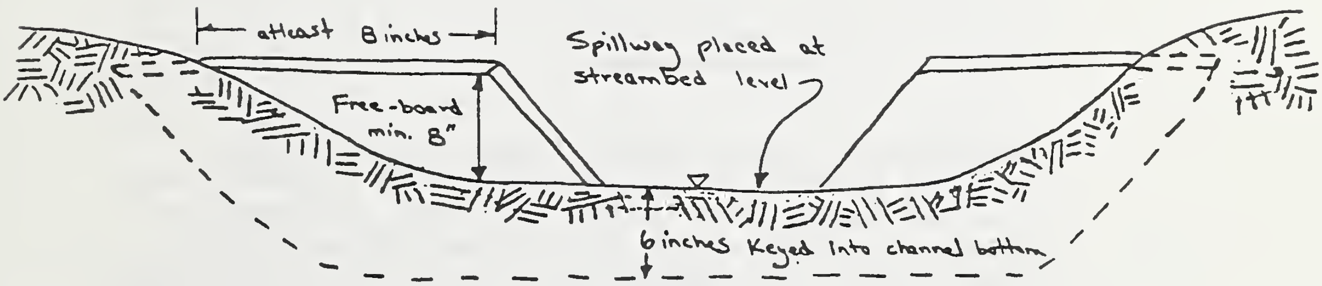
1. Thickness and length of submerged spillways. Submerged spillways are to be constructed from redwood boards long enough to span the entire width of the channel and be keyed into adjacent banks (see B.6.) Redwood board thickness shall never be less than 1 inch and shall be at least 1 1/4 inches thick if submerged spillways are greater than 6 feet long.

2. Free-board height. (see sketch, page 48) Free-board height is the verticle distance between the spillway level and the lowest point of the top of the submerged spillway. Free-board height shall be at least 8 inches.

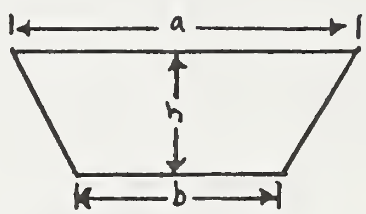
3. Total height. (see sketch, page 48) The toal height of a submerged spillway is the sum of the free-board height and that portion of the structure which is keyed (buried) into the channel bottom. Total height shall never be less than 14 inches; i.e. 6 inches of board surface keyed into the channel below the spillway level, plus 8 inches of free-board.

4. Spillway area. The S.O.W. shall specify the spillway area for submerged spillways to be constructed within a particular reach. A spillway can be cut into the board prior to installing the submerged spillway into the channel.

SUBMERGED SPILLWAY : SCHEMATIC DRAWING



5. Spillway design. Construct the spillway in a form of a trapezoid. The formula to compute area of a trapezoid is: $A = 1/2\ (a+b)\ h$



6. Excavation into channel banks and bottom. Redwood boards shall be keyed into (inset into) channel banks to provide strength and prevent lateral breaching of the submerged spillway. Banks shall be neatly excavated (notched) only enough to key the boards at least 8 inches into the channel banks. It will also be necessary to excavate the channel bottom 6 inches deep to receive the submerged spillway. Once a spillway has been placed into the channel, clean fill material (i.e. no large rocks or organics) shall be packed into the channel bank and bottom where the spillway is inset to create a seal.

7. Anchoring submerged spillways. Submerged spillways shall be securely anchored to the channel by either wooden stakes (1½ inches diameter) or metal rebar. Stakes shall be driven at least 2 feet deep into channel bank and/or bottom, and still have sufficient length to span the free-board height. A minimum of 4 stakes shall be driven: two on each bank with one against the upstream and one against the downstream side of the spillway. When submerged spillways exceed 6 feet in length, two additional stakes shall be driven against the downstream side of the spillway spaced evenly across its length. Stakes shall not extend into the spillway area.

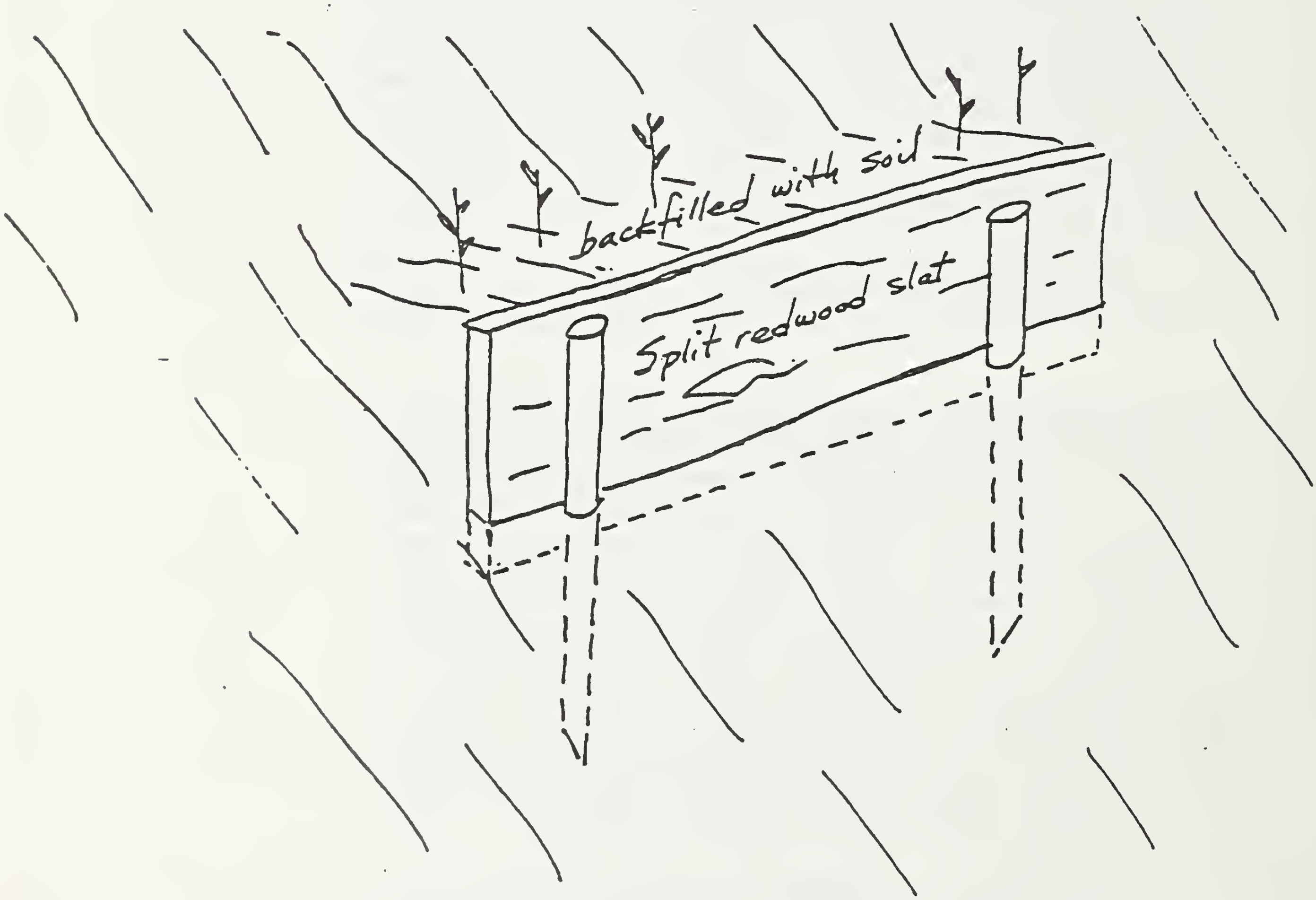
8. Submerged spillway placement. Submerged spillways are always installed with the spillway at streambed level, and perpendicular to the channel. No energy dissipation is required downstream from the spillway. The S.O.W. shall specify the distanc between each submerged spillway. Begin at the

IV.B.8. (cont'd)

bottom of the channel to be treated. Excavate channel banks and bottom to receive the lowermost spillway, and stake into place. Measure channel distance to next submerged spillway as specified in S.O.W., and install the next structure.

V. PLANTER BOXES

Planter boxes can be placed on steep slopes where soil can be easily washed downhill. Planter boxes shall be made of split or milled redwood boards, or other suitable material specified by the S.O.W. Redwood boards shall be 16 inches - 18 inches wide, at least 1¼ inches thick and 4 feet to 5 feet long. In some cases, planter boxes shall be continuous and the length of redwood boards will be determined by hillslope characteristics. A trench at least 3 inches deep shall be dug the length of the redwood board; the redwood board shall be placed vertically and anchored by wood stakes. Stakes greater than 24 inches long shall be driven on the downslope side of the redwood board, spaced no greater than 30 inches apart. Once placed, the redwood boards shall be backfilled.



Planter box on bare soil slope

Wooded terraces protecting a slope against erosion. Terraces are constructed on contour and supported by woody material (limbs, split boards, etc.) which is held in place by stakes.

Planter boxes at base of slope used to intercept soil washed down slope and provide level bench for transplants. Boards are imbedded in the slope and supported by stakes driven on downslope side.

VI. WATER BARS: GENERAL SPECIFICATIONS

A. Waterbars serve to divert surface runoff from bare slope areas (typically skid trails and roads) onto vegetated areas or other areas where the flowing water is less apt to cause soil erosion. To satisfactorily accomplish this purpose, waterbars shall:

1. Be of sufficient dimensions to accommodate the surface runoff they divert without being overtopped or otherwise failing.

2. Be located properly to successfully divert all the water they are intended to intercept (i.e., when used on a skid trail, they shall extend from the inside edge of the trail to slightly beyond the outside edge of the bare soil area.)

3. Be angled down the slope sufficiently to allow water to drain through the trough of the waterbar and freely discharge at the correct end of the structure. Thus, the slope of the waterbar shall be sufficient to drain the intercepted surface runoff without allowing ponding, yet not so steep as to cause erosion or gullying of the bottom of the trough.

4. Be constructed so the lower or discharging end of the waterbar is clear and free from debris and allows for the free discharge of runoff.

5. Be constructed so the point of discharge is onto slash (organic debris), rock, or some other form of energy dissipation. Runoff through the downslope end of the waterbar trough shall not be allowed to erode the soil in that location or within at least three feet immediately downslope. Sufficient energy dissipation shall be provided to prevent future erosion resulting from diversion of flow by the waterbar. Waterbars which discharge on steep bare slopes may cause erosional problems if not installed with energy dissipation at their discharge ends.

VII. CONSTRUCTING NEW WATER BARS (by hand)

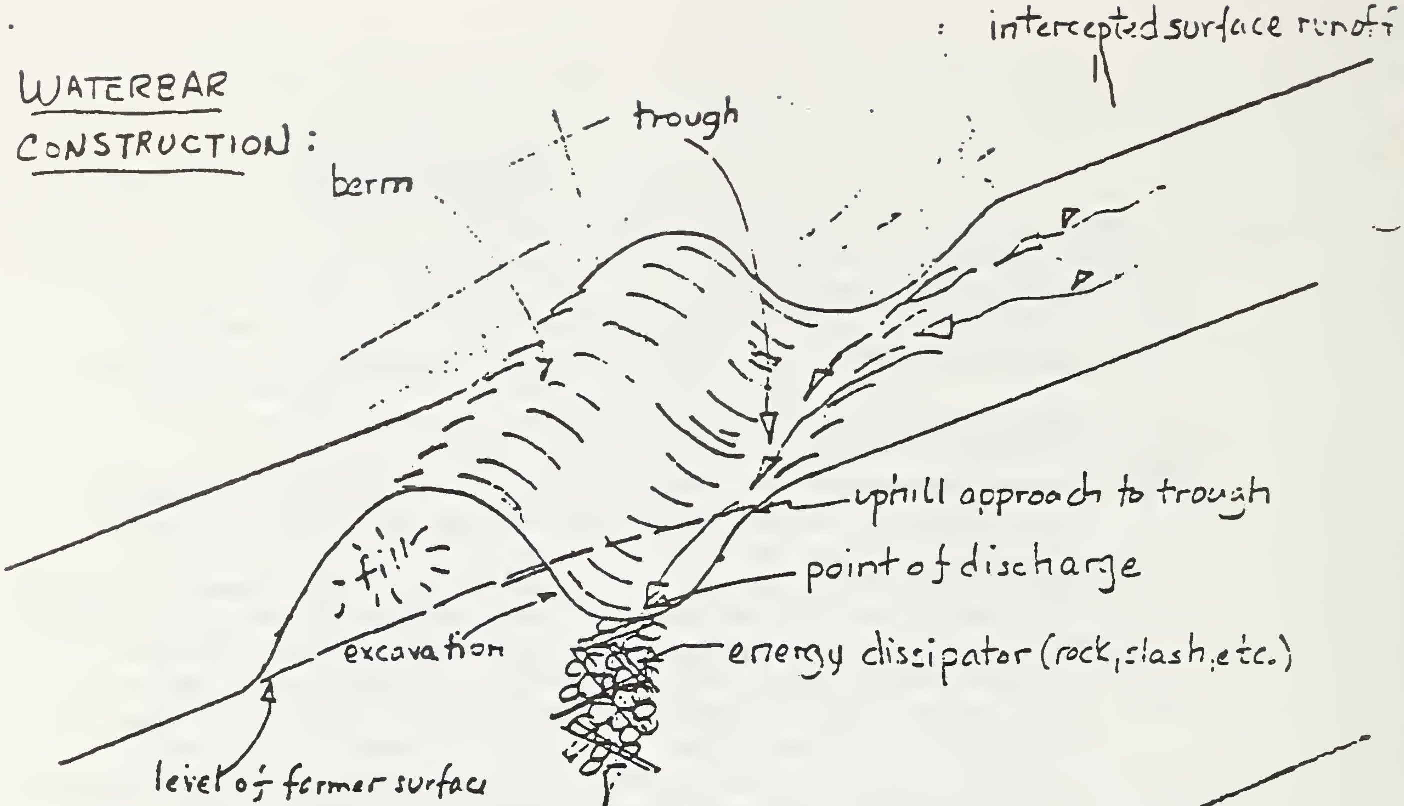
A. Definition of job.

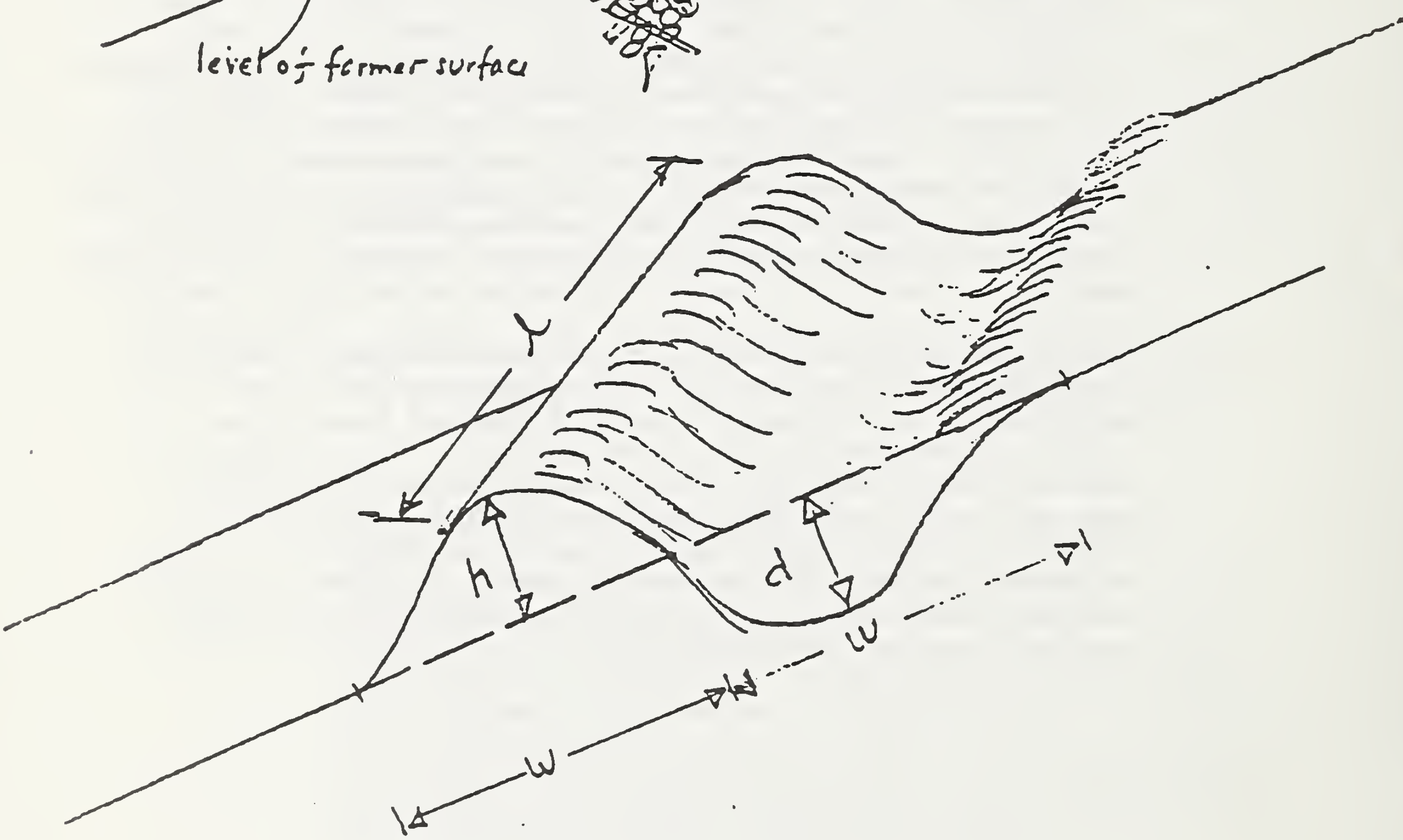
See General Specifications for Waterbars, V, above.

B. Specifications of job. See sketch, page 54.

Waterbars shall be excavated at least 8 inches into firm substrate (d = 8"); trough shall be at least 12 inches wide (w = 12"), with a gentle uphill approach to the trough. Trough shall be free and clear of debris or other obstructions so as to drain freely without ponding water; trough shall have a gentle slope toward the discharging end (there shall be a total drop of 6 inches to 18 inches along the run of a typical 10-foot long trough); trough shall abut inside bank of skid trail or otherwise be constructed to assure total diversion of runoff. Berm shall be at least 8 inches high (h = 8") and 12 inches wide (w = 12"); berm shall be composed of on-site inorganic sediment (rock and subsoil, preferably that excavated from the trough) and shall be tramped with shovel, feet or otherwise hand-compacted. Point of discharge shall be free and clear of debris so as to allow all water to drain freely from the trough. Berm shall be constructed so as not to allow surface runoff to flow over or around it. From point of discharge for a distance of 3 feet (slope distance) downslope, energy dissipation shall be placed in the path of the diverted surface runoff-- this shall primarily consist of rocks 5 to 12 inches in diameter and secondarily (if sufficient numbers of rocks cannot be found within 100 feet of site) of slash or other woody debris no larger than 12 inches in diameter and 24 inches in length.

WATERBAR CONSTRUCTION:





l = length (average = 10')
h = berm height (min = 6")
d = trough depth (min = 6")
w = trough & berm width (min = 12")

VIII. REPAIR EXISTING WATER BARS (by hand)

A. Definition of job.

Waterbars that exist but are presently ineffective or expected to become ineffective shall be repaired to meet the specifications outlined for new waterbars.

B. Specifications for repairing waterbars.

1. Opening or unblocking point of discharge (open end of waterbar).

The discharging end of the waterbar shall be cleared of organic debris, soil and rock which is preventing or hindering the free flow of water from the trough. Energy dissipation shall be placed below the point of discharge if there exists a gully over 8 inches deep and wide at that point and extending at least 3 feet downslope.

2. Clean out trough of waterbar.

The trough shall be cleaned of organic debris, soil and rock so as to allow free drainage through the trough and across the point of discharge. If the bare slope below the point of discharge displays a gully greater than 8 inches in width and depth and 36 inches in length, energy dissipation shall be installed.

3. Extend end(s) of waterbar. (See sketch on waterbar repair, page 56 .)

Additions to the existing waterbar shall be built at one or both ends of the waterbar so as to prevent water from flowing around the waterbar structure rather than being diverted by it. Typically, the upper end is not extended far enough downslope, so the surface runoff entering the trough presently flows around the downslope end of the waterbar rather than through the point of discharge. If not present, energy dissipation shall be provided.

4. Breach waterbars (see sketch on waterbar repair, page 56 .)

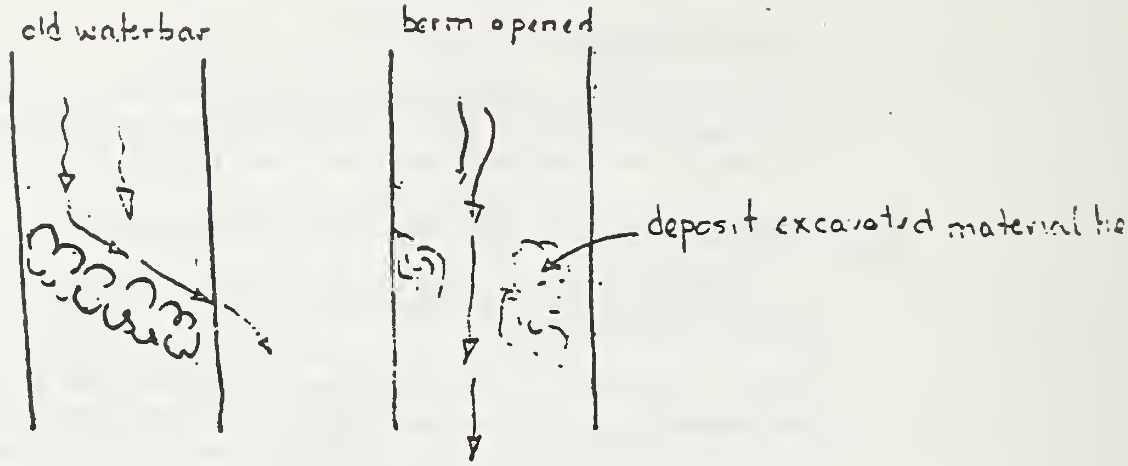
Some waterbars are doing more damage than good at their present location, and so shall be destroyed. To accomplish this, a 4 foot wide cut shall be made directly across the berm at the point opposite where most of the surface runoff is entering the trough

WATERBAR REPAIR:

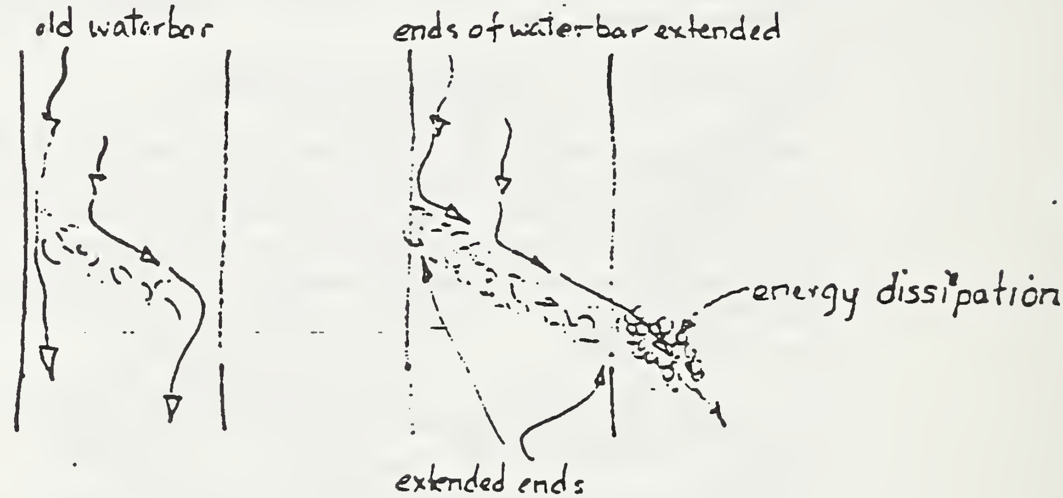
condition

repaired waterbar

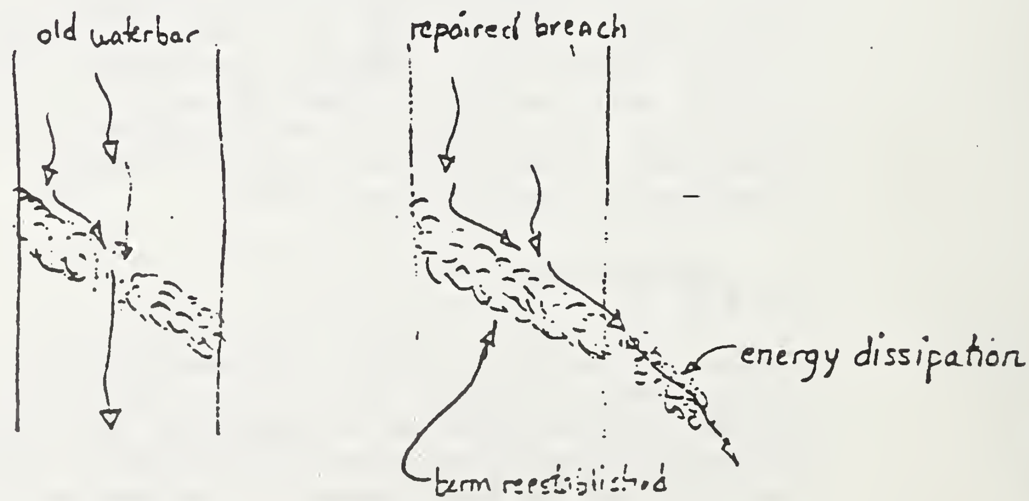
Breach Waterbar



Extend End(s) of Waterbar



Repair Breached Waterbar



VIII.B.4. (cont'd)

from upslope. Excavated material shall be packed into the trough so as to assure all the water entering the pre-existing waterbar will now flow through the opened berm and not down the former trough (this point will likely be located just downslope in the trough below the new cut in the berm, thereby acting as a dam to surface flow.) The berm shall be cut down and the floor of the remaining trough built up to the level of the former surface so the new profile is smooth. The cuts in the berm should be sloped toward each other with at least 2 feet of "flat" channel between.

5. Repair breached waterbar (see sketch on waterbar repair, page 56).

Waterbars that have been naturally over-topped by surface runoff and breached so water now flows across the trough rather than down through the trough need to be repaired. These failed berms shall be filled with compacted material from adjacent bare areas and the waterbars shall then be otherwide modified or repaired to conform to the specifications of a newly constructed waterbar.

IX. HAND-CONSTRUCTION OF DITCHES TO DRAIN WET AREAS

Ditches shall be excavated at least 8 inches into mineral soil. Top width of ditch shall be at least 12 inches; ditch shall slope gently towards direction of discharge (not so steeply as to erode its bed.) Ditch shall be free and clear of organic debris, soil or rocks which could block the flow of water; ditch shall discharge onto slash or rocks or similar energy dissipating materials. Soil excavated during ditch construction shall be piled onto downslope edge of ditch as a continuous berm so as to contain excess flows within ditch area. In swampy areas to be drained, a number of small "feeder" channels shall be etched into the soil to drain standing water and saturated soils towards the beginning of the main drainage ditch.

X. WATTLING

A. Definition of job.

Wattles are bundles of flexible twigs and branches tied together. Wattling is the process of placing wattles in contour trenches on slopes, staking the wattles in place, and then covering the wattles with soil. Once in place, wattles serve to retard surface erosion and revegetate bare slopes through sprouting of roots and branches from the bundles.

B. Specifications of job (see figure 1, page 60, for procedure.)

1. Wattling bundles should be prepared from live material, native to the site. Willow (*Salix* spp.) is generally the preferred plant. Coyote brush (*Baccharis*) may be suitable for dry sites, and non-sprouting, species such as alder (*Alnus*) may be used for wattles as a physical means of erosion control. Specific species for wattling will be designated in the S.O.W.

2. Wattling bundles may vary in length, but must taper at the ends, and the longest stems shall be 1 1/2 feet longer than the average length of the stems to achieve the taper. Butts of individual stems shall not be more than 1 1/2 inches in diameter.

3. Stems should be placed alternately in each bundle so that approximately half the butt ends are at each end of the wattle.

4. Bundles shall be tied at not more than 15-inch spacings with 2 wraps of binding twine, or heavy tying material, with a non-slipping knot. When compressed firmly and tied, each bundle shall be approximately 8 inches in diameter (minimum, 6 inches; maximum, 12 inches.)

5. Bundles shall be cut and tied not more than one day in advance of placement and the bundles shall be kept covered and wet between the time of cutting and installation. Cutting, tying and placing in trenches on the same day is desirable.

X. B. (Con't)

6. The grade for the wattling trenches should be staked out (see specifications 10 and 11 below) with an Abney level, string level, or similar device, and shall follow slope contours, (i.e. horizontal trenches.)

7. Trenches shall be spaced three feet apart, vertically, unless otherwise specified in the S.O.W.

8. Bundles shall be laid in trenches dug to a depth equal to the diameter of the bundles, with ends of the bundles overlapping at least 12 inches. The overlap shall be as long as necessary to permit staking as specified below.

9. Bundles shall be staked firmly in place with vertical stakes on the downhillside of the wattle at no more than 36-inch spacing or closer if stated in the S.O.W. and at least one stake shall be driven through each bundle. In any case, a bottom stake should be placed at the mid-point of the bundle overlap.

10. Stakes shall be greater than 1 1/4 inches in diameter and 24 inches long.

11. All stakes shall be driven to a firm hold and at least 15 inches deep. Where soils are soft and 24-inch stakes are not solid, longer stakes as necessary should be used. Where soils are rocky and/or compacted, steel bars should be used to open up stake holes for the stakes. Stake depths may be waived by the Contracting Officer or his/her representative on a site-specific basis at difficult sites where it is impossible to always meet minimum stake depths.

12. Work shall progress upward from the bottom of the slope to be wattled. The buried wattles shall have soil firmly tramped around them to minimize the possibility of drying out, however, the terracing effect created by the contour trenching shall be preserved.

WILLOW WATTLING PROCEDURE:

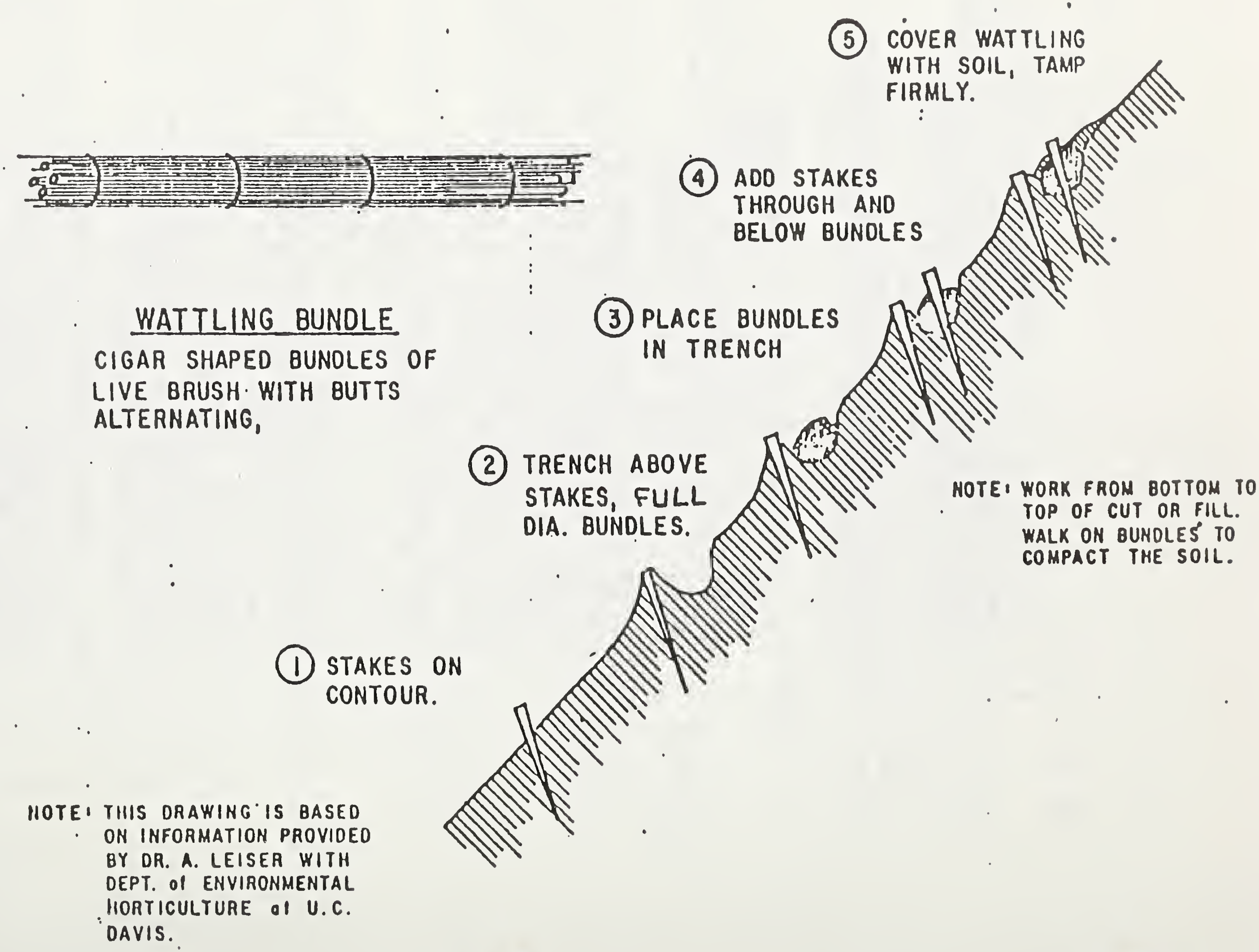


Figure 1

XI. STEM CUTTINGS

A. Definition of job.

A stem cutting is a shoot, or cane, cut from a live tree or shrub. Cuttings from sprouting plant species will grow if planted in the ground under certain conditions.

B. Specifications of job.

1. Preparation of cuttings:

   a. From healthy wood of a sprouting plant species native to the planting site.

   b. Reasonable straightness.

   c. Clean cuts with unsplit ends.

   d. Length: 12-inch minimum length.

   e. Diameter 1/4 - inch minimum diameter; the thicker the cutting, the greater the reserves. Therefore, cuttings greater than 1 inch are desireable, though their numbers may be limited by the supply.

   f. Stem cuttings shall not be from the tips of branches but rather farther back on the stems. The top of each cutting shall be just above a leaf bud, the bottom cut just below one.

   g. Trim branches from cuttings as close as possible.

   h. At least 2 lateral buds shall be above the ground after planting. (see sketch, page 63 .)

2. Leaves shall be stripped from cuttings used before normal leaf fall occurs.

3. Handling of cuttings between cutting and planting: Cuttings must not be allowed to dry out. Cuttings may be planted the same day, and at all times must be kept covered and moist during transport and storage before planting. Under certain dry conditions of either the cutting site or the planting site, the Contracting Officer or his/her representative may require that cuttings be soaked at least 1 day prior to planting, though mandatory soaking will be uncommon. At no time

shall a cutting be left exposed to the air to dry out prior to planting.

4. Planting of cuttings: Cuttings must be planted right -side-up. At least 50% of the cuttings length should be planted in the ground; it is preferable if 75% of the cutting length is in the ground, but at least two budding nodes shall be left exposed above ground. Deep planting minimizes loss of water due to transpiration. Soil shall be firmly pressed around cutting to reduce moisture loss.

5. Time of cutting planting: Basically, planting time is between September and April; earliest possible planting time for wet sites is after first major storm in fall (greater than 1 inch rain.) For dry sites, earliest planting time is after second major storm. Latest possible date is dependent on the particular year, but approximately March 1st. Additional soaking prior to planting may be required for late plantings. Optimum planting time is October through February, when ground is wet and plant material is dormant.

6. General locations for use of cuttings.

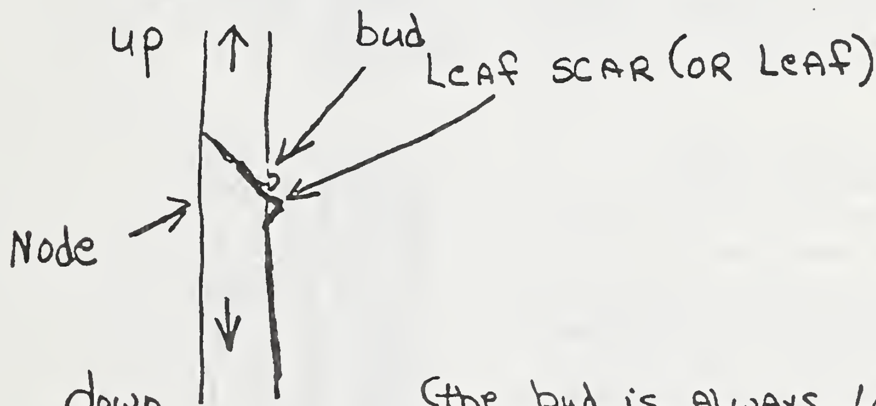
   a. Slopes: bare soil areas that show evidence of recent movement or active erosion of surface particles. Especially well suited for cuttings are persistent wet areas, road-cut slopes where soil conditions permit, and raw soil areas on slumps.

   b. Gullies and channels: areas best suited to use of cuttings are the floors and banks of small incipient gullies, sediment fill behind check dams, raw gully banks, berms of water bars and the area just below water bar outlets, if suitable soil conditions exist.

   c. In addition, any other location where cuttings may be deemed useful in establishing vegetation for minimizing erosion.

C. Cutting Willow and other brushy species for planting.

Cutting of plant material for use as wattles or cuttings will be done to minimize disturbance of vegetation and soil adjacent to the willow stands. Conifers must not be damaged. Ground cover must be preserved as much as possible; trails with bare soil from trampling the brush must not occur. Willows should be used as efficiently as possible; i.e., when stakes for wattles are cut, excess branches should be used as cuttings or wattle bundle material. Willow shoots must be cut by either pruning shears, hand saw or chain saw. Branches from willow must be cut diagonally to expose more surface area to water and to provide a pointed end for stake driving and sprig planting. The basal ends of the shoots must be marked clearly in some manner so workers can determine which end to plant. Correct species identification is essential, particularly in the willows (see figure 2, page 64 .) which often look similar but have different habitat requirements which in turn may result in different survival success. Species identification should be confirmed by qualified Park personnel before collection.



(the bud is always located just above the leaf scar or leaf. Use this fact to deteemine proper orientation of cuttings)

Salix sitchensis Sanson.

Sitka Willow. Fig. 1228.

Salix sitchensis Sanson, in Bongard, Mem. Acad. Imp. Sci. St. Petersb. VI. 2: 162. 1833.

Shrub, 2–7 m. high, branchlets slender, dark brown to black, dull to sublustrous, glabrous or rarely pubescent; leaves spatulate-obovate or the upper oblong-obovate, cuneate at base, mostly acute at apex, entire or obscurely crenate, 4–7cm. long, 1.5–2.5 cm. wide; dull green (the young pubescent) above, with impressed veins, covered beneath with a short appressed satiny pubescence; aments coetaneous, long, slender, densely flowered, subsessile to short-pedunculate, 2–8 cm. long; capsules ovate-conical, acute, subsessile, 4–6 mm. long, silky-pubescent; style 0.5–0.7 mm. long; stigmas short, entire, erect; stamen 1, filament glabrous, anthers violet (?); scales oblanceolate, brown, thinly villous.

Along streams, low elevations, Transition and Canadian Zones; southern Alaska to southwestern Oregon (and northern California?), east to northeastern Oregon and western Montana. Type locality: "Indian River, near Sitka, Alaska."

Juncus effusus L.

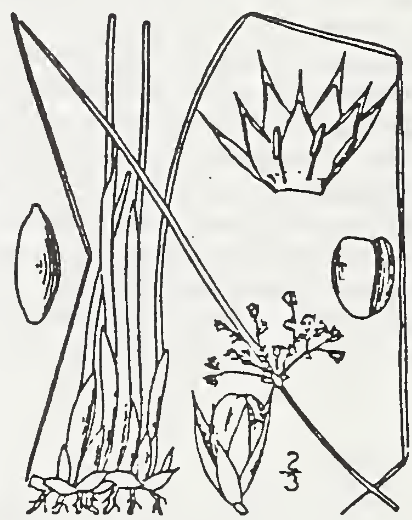
Common Rush, Bog Rush, Soft Rush. Fig. 857.

Juncus effusus L. Sp. Pl. 326. 1753.

Stems densely tufted, from stout branching proliferous rootstocks, 5–15 dm. high, soft. Basal leaf-blades reduced to short filiform rudiments; inflorescence many-flowered, 2.5–10 cm. long; lowest leaf of the inflorescence appearing as a prolongation of the stem, 5–20 cm. long; perianth 2–3 mm. long, green, lanceolate, acuminate; stamens 3, the anthers shorter than the filaments; capsule obovoid, 3-celled, muticous, regularly dehiscent; seeds reticulate in about 16 longitudinal rows, the reticulations smooth, two or three times broader than long.

In swamps and moist places, Canadian to Upper Sonoran Zones; nearly throughout North America, also in Europe and Asia. Common throughout the Pacific States except the desert areas. Type locality: Europe.

Juncus effusus brunneus Engelm. Trans. St. Louis Acad. 2: 491. 1868. (*Juncus effusus hesperius* Piper). Distinguished from the typical form by the usually more compact panicle and dark brown perianth and capsule. This is the common form along the coast, extending from British Columbia to southern California.



Juncus bolanderi Engelm.

Bolander's Rush. Fig. 895.

Juncus bolanderi Engelm. Trans. St. Louis Acad. 2: 470. 1868.
Juncus bolanderi riparius Jepson, Fl. Calif. 1: 255. 1921.

Stems from creeping rootstocks, slender, 5–8 dm. high. Basal sheaths bladeless; stem leaves 3–4, their sheaths with conspicuous auricles; the blades slightly compressed, 10–20 cm. long, 1–1.5 mm. wide, distinctly septate; heads 2 or 3 or sometimes solitary, many-flowered, subglobose; perianth 3.5 mm. long, greenish brown, the segments na rowly lanceolate, setaceously acuminate; stamens 3; anthers much shorter than the filaments; capsule clavate-oblong, shorter than the segments, obtuse and apiculate at the apex; seeds minute, obovate, reticulate.

Stream banks and swamps, Humid Transition and Upper Sonoran Zones; Umpqua Valley, Oregon, to Mendocino County, California, also occurring locally in the lower Sacramento Valley and Orange County. Type locality: swamps near Mendocino City, California.

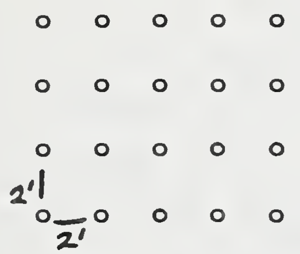
Figure 2 from:

Abrams, Leroy 1940. Illustrated Flora of the Pacific States. Stanford University Press, Stanford, California.

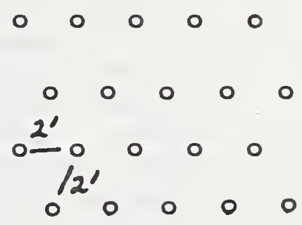
XI. (Con't)

D. <u>Placement of stem cuttings and transplants.</u>

The required planting distance between transplants and/or stem cuttings will be stated in the S.O.W. as "2 foot spacing" or "3 foot spacing" etc. The rows must be staggered rather than be in columns:



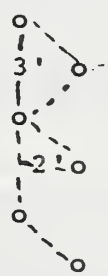
2 foot spacing
<u>Wrong</u> <u>Way</u>



2 foot spacing
<u>Right</u> <u>Way</u>

Where the contract specifies planting in a zigzag pattern, <u>x</u> foot spacing, <u>y</u> foot offset, a double row is desired with x number of feet between each cutting or transplant in that row and the second row y # of feet to the side,

Ex: zigzag pattern, 3 foot spacing, 2 foot offset



XII. TRANSPLANTS

A. Definition of job.

Transplanting is the intact removal of an individual plant from one place and replanting it in another.

B. Specifications of job.

1. An adequate size of root ball is necessarily a judgemental decision best made on a plant by plant basis in the field but all plants must be dug with a ball of soil containing at least 60% of their roots. If the soil is dry, the soil around the plant shall be soaked prior to digging so that the root ball will hold together. Plants must be transported to the site in such a way that the root ball does not shatter, exposing the roots. (Size of transplant and root ball varies with species, see species specific specifications below.)

2. All species shall be replanted within a maximum of 24 hours of being dug up. The root ball must be kept moist at all times to keep the roots from drying out.

3. The planting hole shall be large enough to accommodate the root ball easily, without cramping, bending or cutting roots. Adjust planting depth so that the old soil line (usually visible near the base of trunk or stems) is at the surface level of soil surrounding the planting hole.

4. The hole shall then be refilled about 3/4 full with soil, firming it around the roots and thoroughly watered. If settling occurs the plant shall be readjusted and the remaining soil added, again firming the soil to eliminate any air pockets.

5. Transplants shall be obtained in such a way that at least one half of the original plants of the species remain scattered within the collection area. The source area <u>must not be</u> denuded of plants.

6. Holes created by removal of plants shall be filled with soil to the original soil surface.

7. Alder (Alnus oregana), coyote brush (Baccharis pilularis var. consanguinea) and rhododendron (Rhododendron macrophyllum) transplants: Minimum size plants shall be 6 inches high; maximum, 24 inches high. The larger the plant, the larger the root ball. At a minimum the surface circumference of the root ball shall equal the circle made at the drip line of the plant's canopy.

8. Deerfern (Blechnum spicatum) and sword fern (Polystichum munitum) transplants:

   Minimum basal diameter of fern dump shall be 4 inches. Root ball shall include a minimum of 75% of plants roots.

9. Rush "plugs""

   Correct species identification is essential. Figure 2 and the accompanying descriptions are taken from Abrams Illustrated Flora of the Pacific States. Species identification shall be confirmed by qualified Park personnel before collection.

   Juncus "plugs" each with a 2 inch minimum basal diameter, may be obtained by dividing larger clumps.

10. Salal (Gaultheria shallon) and yerba de selva (Whipplea modesta) transplants:

    Both species root at the nodes though salal does so less frequently. Transplants shall have root balls at least 8 inches in diameter and it is desirable to include at least 10 inches of the underground stems whenever encountered. Large plants may be divided, provided each division has the 8" root ball.

C. Placement of transplants.

See XI. D. Placement of stem cuttings and transplants Page 65 .

XIII. GRASS SEED AND FERTILIZER APPLICATION

A. Definition of job.

Grass seed and fertilizer are hand spread with "belly grinders" within areas flagged by Park personnel. Application rates are predesignated and seed and fertilizer provided. Grass will serve as an immediate, temporary ground cover to decrease surface erosion.

B. Specifications of job.

1. When stored on-site, fertilizer is to be protected from dew and rain by plastic tarps which will be provided. Grass seed must be stored under dry, cool conditions and protected from mice.

2. Application rates are listed as pounds of seed and pounds of fertilizer to be used.

3. Occasionally no fertilizer is to be applied. This will be noted in the site-specific instructions.

4. Scales for weighing, buckets, "belly grinders" and rakes are to be provided by the contractor.

5. When a mixture of seeds with very different sizes and weights is to be applied care must be taken to ensure that seeds are evenly distributed in the mix, insuring in an even distribution on the ground. Since smaller seeds will settle to the bottom it may be necessary to periodically shake the belly grinder to redistribute the seeds.

6. Seed and fertilizer are to be applied as soon as possible after slope work (contour terraces, wattling, wooded terraces) is completed in order to take advantage of warm temperatures accompanying the first fall rains. Seed and fertilizer are to be applied before mulching.

7. Seed and fertilizer (applied separately) <u>must</u> be spread uniformly over entire area.

8. Unless otherwise specified, seed and fertilizer are to be raked into the soil immediately after application, covering them with 1/8 to 1/4 inch of soil.

XIV. STRAW MULCH

A. Definition of job.

Straw from bales provided by the Park is spread over a predesignated area at an application rate set by Park personnel. The straw will protect the soil surface from rainfall impact and help to retain soil moisture.

B. Specifications of job.

1. Straw shall be spread evenly within the flagged area. The amount to be spread will be given in number of bales (example; 3.5 bales.)

2. Bales are provided on site but it will sometimes be necessary to transport them to the specific work area. Prospective contractors will be shown the location of the straw during the pre-bid "show-me" inspection of site.

3. Baling wire shall be removed from the site and properly disposed outside the park.

4. Mulch will be the last task performed on the work area, following any contour terracing, wattling, wooded terraces, transplants or grass and fertilizer application.

XV. WATER LADDERS

A. Definition of job.

Water ladders are wooden structures, similar in appearance to ladders, which serve to convey water across a steep slope while preventing channel downcutting. They serve the same purpose as half-round culverts that conduct ditched or culverted water over steep road fills onto vegetated and/or slash-covered slopes. Essentially, water ladders are energy dissipation devices that can effectively handle concentrated runoff, and which work well in conjunction with strategically placed slash and planting of sprigs.

Water ladders can be used in combination with check dams or at the downstream end of cross road drains. Alternatively, water ladders may be used in lieu of check dams where dam installation is difficult because of unstable banks or difficult excavation of channel beds.

B. Specifications of job.

1. Construction of Ladder. Ladder construction will be left up to the discretion of the contractor, but the following criteria must be met in construction:

a). Ladder must be at least 18 inches wide unless it is to be placed in a well-defined gully which is less than 18 inches wide. In all cases, the ladder must be as wide as the bottom of the ditch or drainage channel directly above the ladder

b). Ladder treads must overlap and dip slightly downhill once the ladder is installed. Grooves (about one-half inch deep) may be cut into the top side of the treads to help direct flow towards the center. Bevelling of the leading edge of the treads and nailing of slats under the treads may also be used to help prevent backflow under the treads (see illustrations).

c). Where necessary wing walls should be installed at the top of a ladder to insure that all runoff is directed into the ladder. This may be especially important on wide or poorly defined channels.

d). Outlet areas below ladders should be defended with adequate energy dissipation measures (rocks, slash, sprig plantings, etc.).

B. <u>Specifications of job (cont)</u>

2. <u>Placement of ladder</u>. Ladders must be sufficiently inset into the slope so that runoff will course <u>over</u> the ladder treads and not run under or around the ladder.. Adequate excavation and especially careful placement of the top of the ladder relative to the ditch or drain are crucial. Improperly placed ladders that do not successfully convey runoff <u>over them</u> (during the first winter season) must be re-installed on request of the Contracting Officer.

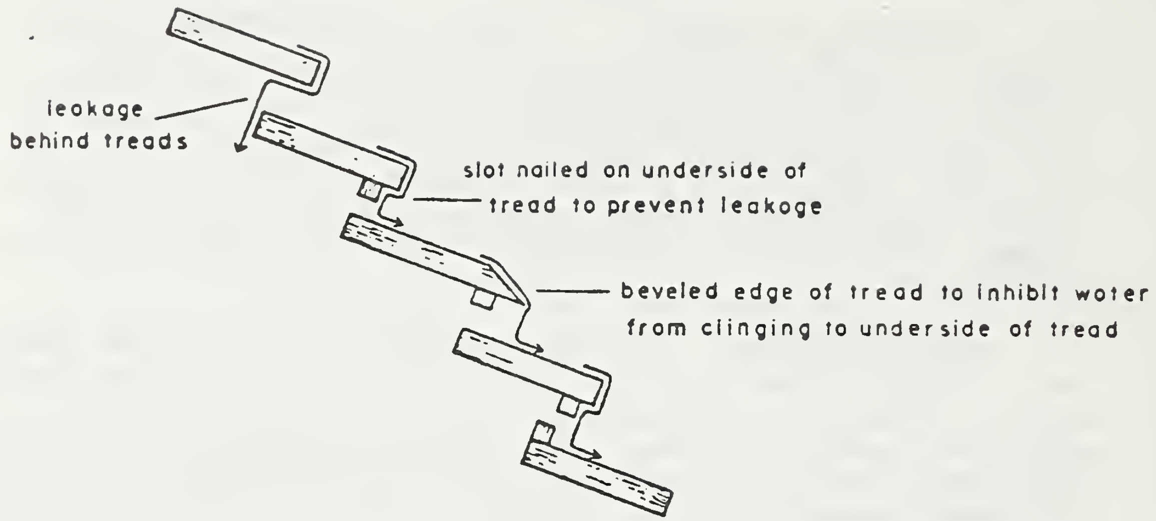
3. <u>Type of ladder</u>. Type and composition of water ladders will largely depend on availability of materials and equipment at the site. Boards of rot resistant wood cut on site with an Alaska mill or similar equipment are preferable. Hand split and hand sawed boards can be used but may pose problems because of their uneven surfaces. These permit water to leak through cracks thus causing possible undercutting of the structure. Dry wood shims should be hammered into all cracks and seams in this case to seal them off. The following are examples of water ladders that can be constructed:

Type 1 - Hand split redwood ladder with log supports

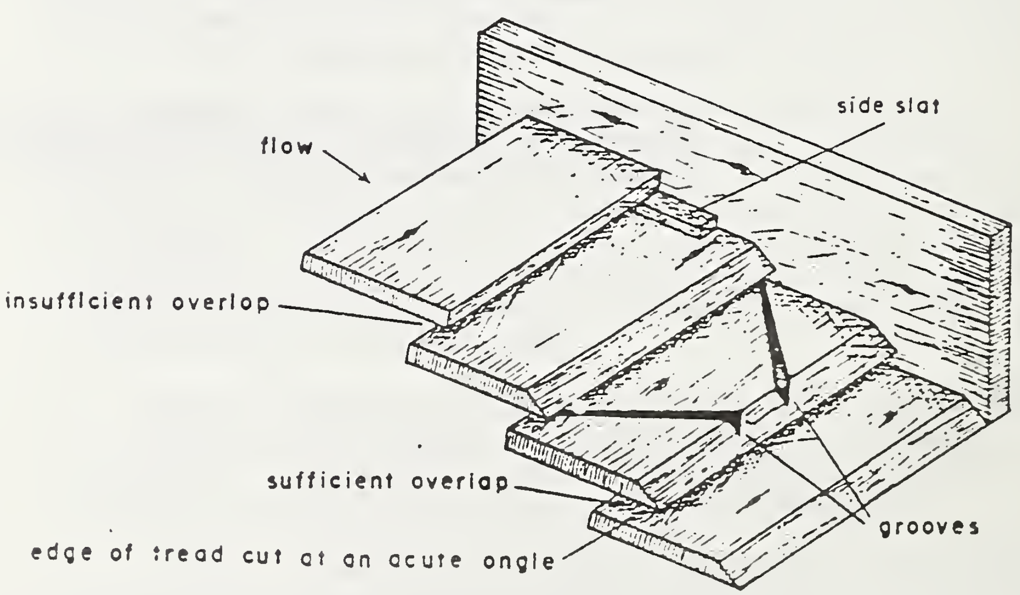
Ladder is built in two overlapping sections, conforming to channel gradient. Top tread of ladder is keyed into a partially buried log (see illustrations).

Type 2 - Milled redwood ladder

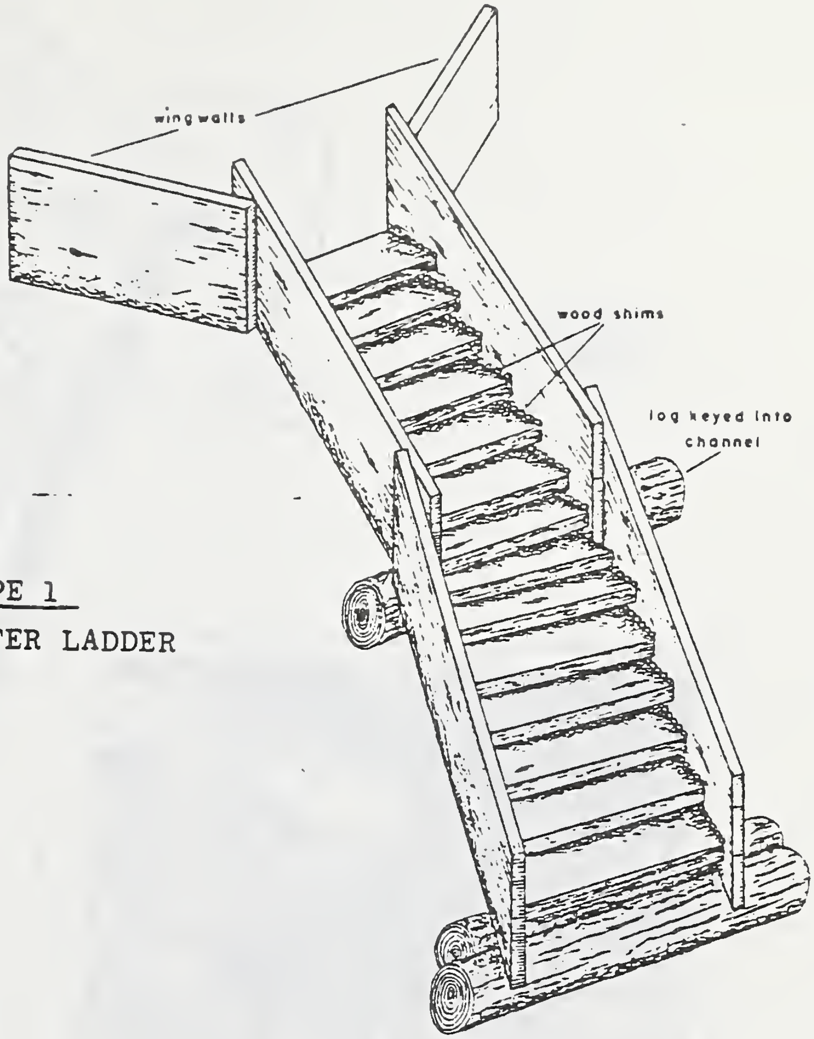
Ladder is constructed from milled redwood slabs and boards. Treads are supported on stair-stepped slats (see illustration).



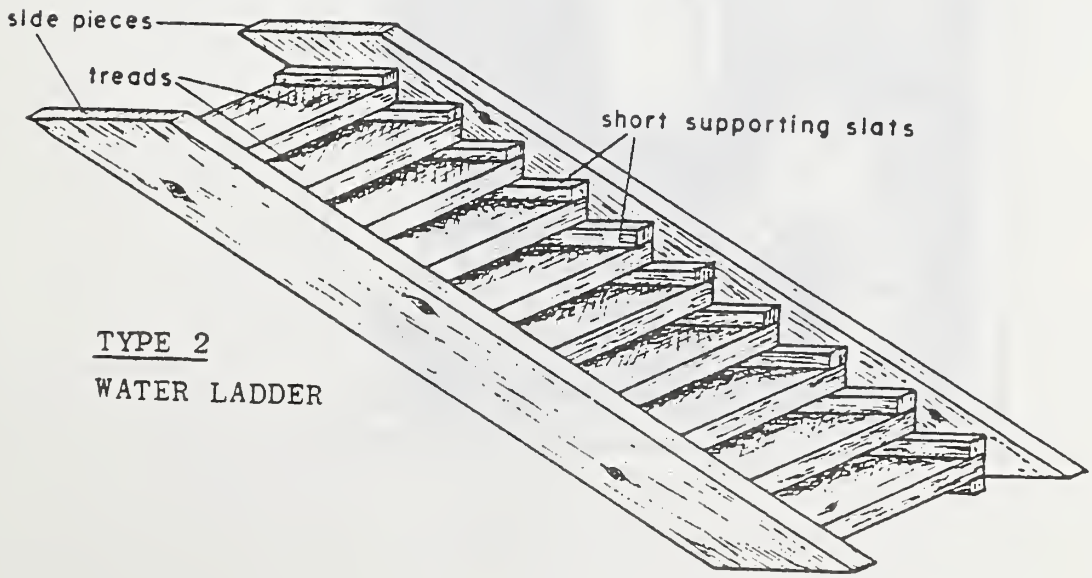
Side view of water ladder treads



Oblique view of water ladder treads



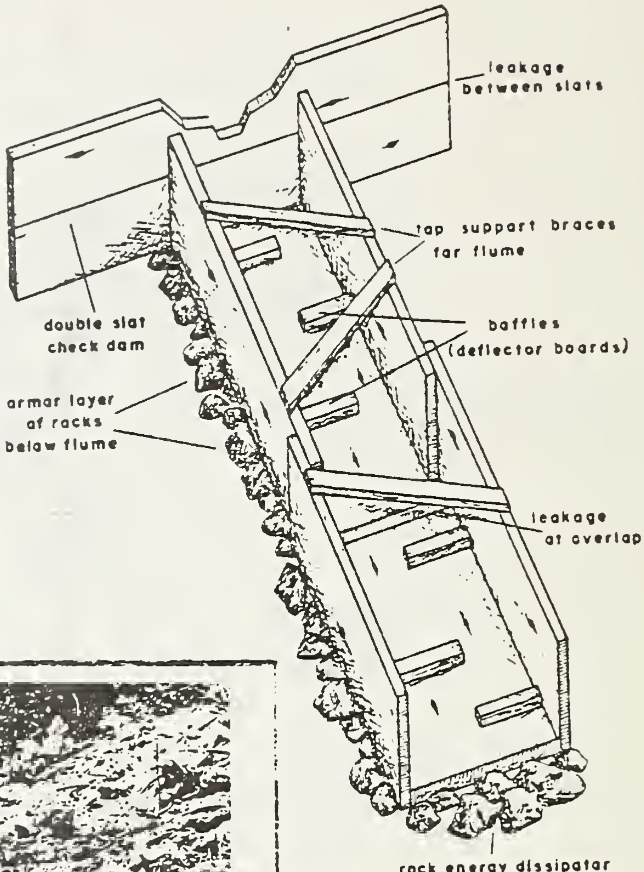
TYPE 1
WATER LADDER



TYPE 2
WATER LADDER

TYPE 3

WATER FLUME



Water flume is keyed into base of check dam system. Note energy dissipator (staked and wired rocks) beneath flume outlet.

PROBLEM NO. 6 - SOIL LOSS ESTIMATES

Assume Ann Arbor, Michigan as the locale of a construction or development site. The site is 40 acres in size, however, only 20 acres will be disturbed by grading and construction.

The following soil and topographic conditions are encountered at the site:

	disturbed area	undisturbed area
ave. slope length, ft	400	600
ave. slope gradient, %	6	10
soil type	Miami silt loam	(K = 0.37)
vegetation factor	1.0	0.12

QUESTION #1 - Compute the total, annual soil loss from the site in the absence of any soil erosion control measures. Give answer in both tons and cubic ft. of soil.

Assume the construction period lasts 12 months during which time the disturbed areas lie fallow and exposed for 3 months. Seed, fertilizer, and straw mulch are then applied. The vegetation establishment period lasts another 3 months during which the representative vegetation (or C-factor) value is 0.4. The vegetation factor for the balance of the construction period is 0.2.

In addition to seeding and mulching, a small sediment basin is also constructed at the site with a total capacity of .137 acre-ft. The relationship between trap efficiency and capacity/inflow ratio is shown in Figure 1. The basin receives sediment from only 70% of the construction area.

Storm runoff or inflow to the basin can be estimated from precipitation data for the area. Assume the worst conditions occur during the winter-spring. A typical, hourly rainfall distribution for a 5-year frequency rain is shown in the table below. The tabulated values express the rates of hourly rainfall in terms of percent of 24 hour rainfall. Figure 2 gives total 24-hour precipitation as a function of storm frequency.

Successive Time Units-hrs	Proportion of Total Precip-%
1 (max)	24
2	14.5
3	10.9
4	8
5	6
6	5
7	4

In Southeast Michigan the average value of infiltration capacity is 0.1 in/hr in winter-spring. The retention is approximately 0.10 in. (In summer the values change to 0.4 and 0.15 respectively). Assume the effective drainage area at the construction site is 50 acres.

QUESTION #2 - Estimate the total soil loss from the site with the erosion control system and the percent effectiveness of the control system (for the disturbed area only). Note: If you are unable to calculate the runoff from the precipitation data, use a rule-of-thumb estimate of 0.1 acre ft/acre of drainage area.

QUESTION #3

What will be the ratio of annual soil losses at two construction sites in Ann Arbor which have the following site and soil conditions. Assume both have the same areas.

Site No. 1

soil:
- 65% silt + very fine sand
- 5% sand (0.1 to 2.0 mm)
- 3% organic matter

site:
- completely disturbed
- 600' ave. slope length
- 10% ave. slope gradient

Site No. 2

soil:
- 40% silt + very fine sand
- 40% sand (0.1 to 2.0 mm)
- 4% organic matter

site:
- weeds & wild grass cover
- 1000' ave. slope length
- 8% ave. slope gradient

Use the Wischmeir nomograph to solve this problem.

Question #1

Disturbed area (20 acres)

Ave. slope length: 400 ft
-"- -"- gradient: 6% } LS = 1.3

K = 0.37

C = 1.0
R = 100

Undisturbed area 20 (acres)

Ave. slope length: 600 ft
-"- -"- gradient: 10% } LS = 3.3

K = 0.37

C = 0.12
R = 100

Computation of soil loss:

Disturbed area: $A_1 = R.C.K.LS = 100(1.0)(0.37)(1.3)(20 \text{ acres}) = 962$ Tons

Undisturbed -"- : $A_2 = R.C.K.LS = 100(0.12)(0.37)(3.3)(20 \text{ acres}) = 293$ Tons

Total Annual loss: $962 + 293 = 1255.0$ Tons or:

$$1255(0.87) = 1091.85 \text{ Cu. Yds} = 3^3(1091.85) \text{ cu.ft.} =$$
$$= 29,479.95 \text{ cu.ft.}$$

Finally: Annual Soil Loss = 1255.0 Tons or
29,480.0 cu. ft.

Question #2

The difference now is, that we will have to compute a weighted value of C-factor, for the disturbed area, and that we will have to compute the value of P-factor (due to the existance of sediment basin).

Computation of C-value

3 months : C = 1.0

3 —"— : C = 0.4

6 —"— : C = 0.2

12 months

The weighted average for 12 months period will be:

$$\underline{C} = 1.0\frac{3}{12} + 0.4\frac{3}{12} + 0.2\frac{6}{12} = 0.25 + 0.1 + 0.1 = \underline{0.45}$$ ✓

Computation of P-value

Find the inflow from the drainage area:

From Fig. 2 the total (24-hour) precipitation for a raintall with 5-year frequency during the Winter-Spring, is: 2.3 inches.

Now we can lay out the following Table:

Time Units hrs	Proportion of 24-hour prec., %	Rate of Rainfall iph	Infiltration rate, fa, iph	Depth of rainf. fe, in
1	24	0.55	0.1	0.45
2	14.5	0.33	0.1	0.23
3	10.9	0.25	0.1	0.15
4	8	0.18	0.1	0.08
5	6	0.14	0.1	0.04
6	5	0.115	0.1	0.015 ✓
7	4	0.09	0.1	—
			Total =	0.965 in

The retention is: 0.1 in, so the final depth of raintall will be: 0.965 − 0.1 = $\underline{0.865 \text{ in}}$ ✓

The inflow due to the drainage area will be:

Inflow = (effective drainage area)(rainfall excess depth)

Inflow = 50 acres (0.865 in) = 43.25 acre-in = 3.6 acre-ft ✓

The capacity/inflow ratio will be: $\frac{0.137}{3.6} = 0.038$

From Fig. 1, the sediment trap efficiency of the sediment basin will be: 70%, for ratio = 0.038.

The sediment basin receives sediment from 70% of the construction area. So the factor P for the basin will be:

$P = 1.0 - 0.7 \times 0.7 = 0.51$ ✓

Computation of the effectiveness of the control system

% Effectiveness = $(1 - CP) \times 100$ Where: $C = 0.45$

$P = 0.51$ ✓

Effectiveness = $(1 - 0.45 \times 0.51) \times 100 = 77\%$ (for disturbed area)

The soil loss from the disturbed area will be:

$A_1 = R.LS.K.C.P.(\text{Area}) = 100(1.3)(0.37)(0.45)(0.51)(20) = 220.8$ Tons

The soil loss from the undisturbed area will remain the same as in question # 1. $A_2 = 293$ Tons.

Total soil loss: $A_1 + A_2 = 220.8 + 293 = 513.8$ Tons or

$513.8(0.87) = 447.0$ cu. yds = 12,069.2 cu. ft ✓

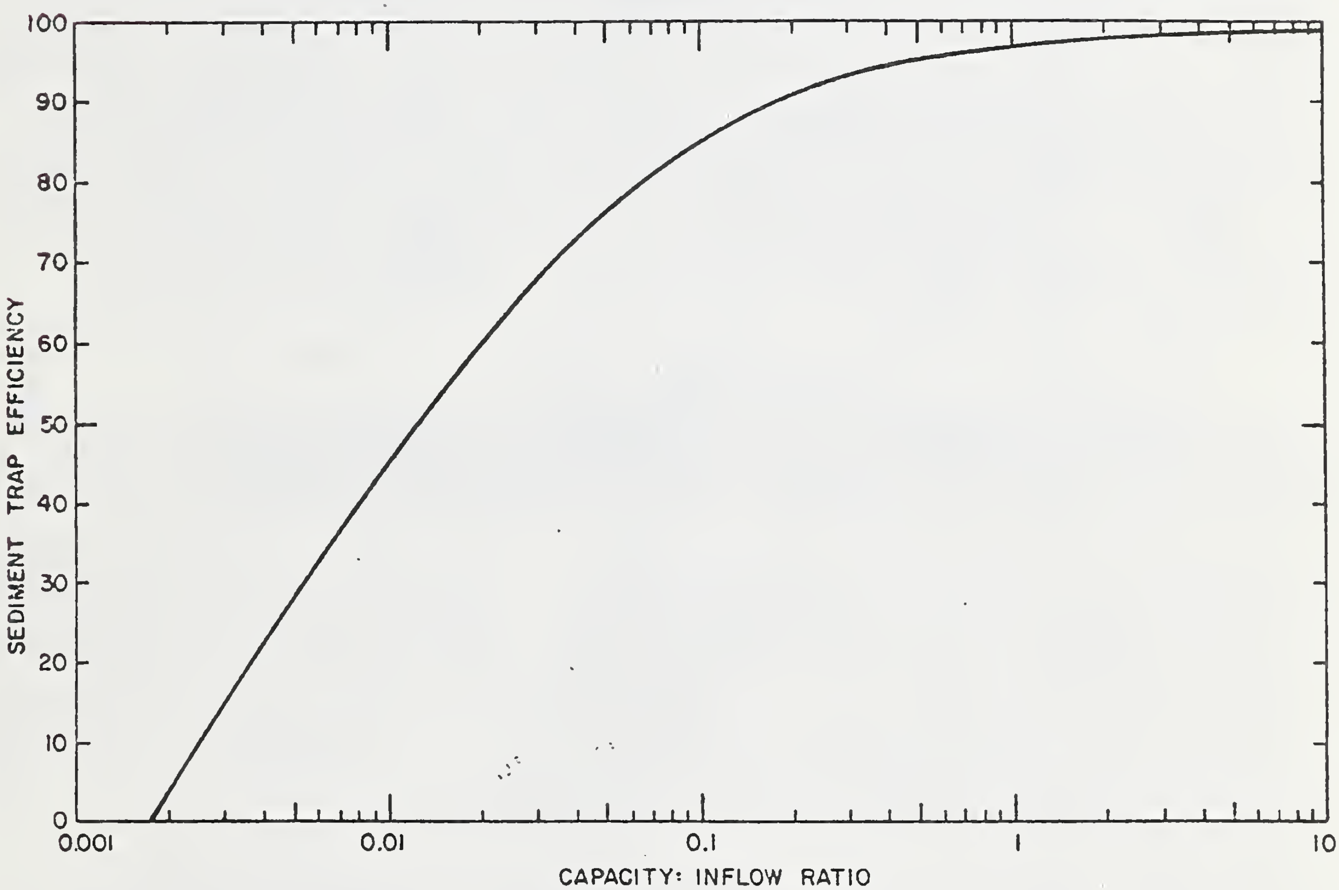


Figure 1. Relationship Between Capacity/Inflow Ratio and Sediment Trap Efficiency of Reservoirs

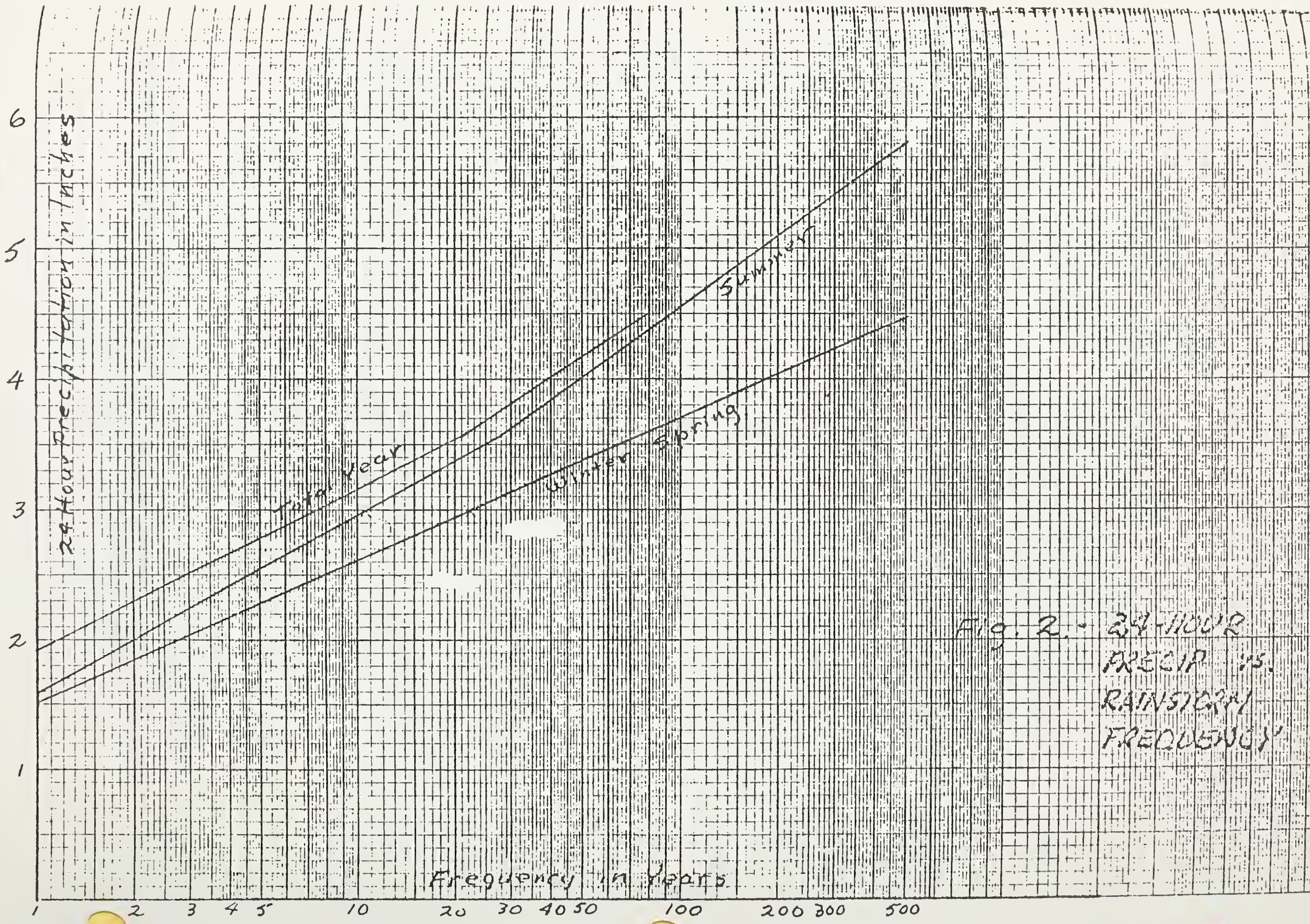


Fig. 2. - 24-HOUR PRECIP. vs. RAINSTORM FREQUENCY

ESTIMATING

Sample Calculations

SHEET-RILL EROSION AND SEDIMENT YIELD ON DISTURBED WESTERN FOREST AND WOODLANDS

Display 3.3-1
Transect
Highlead Logging Data

Location and Size

Acres	80
County	Yamhill
Lat. N	45°00'
Long. W	123°30'

Average Buffer Data

Percent Slope to Channel	42
Slope length to channel	200
Future Slope length/channel	220

Average C Factor Elements

	Present	Future
Effective Canopy Cover Percent	60	60
Effective Canopy Height feet	4	4
Root Network Percent	70	91

Average Transect Data

Transect Elements	Present				Future			
	Log paths	Road Land	Fire Trail	Un-dist.	Log paths	Road Land	Fire Trail	Un-dist.
% Bare Ground	5.0	3.0	5.3	-	3.0	2.5	3.5	-
% Protected Ground	3.7	2.0	3.0	78.0	3.7	2.0	3.0	81.3
% Slope	34	5	30	-	34	5	30	-
Slope Length	133	40	55	-	107	30	20	-
% Area	8.7	5.0	8.3	78.0	6.7	5.5	6.5	81.3

2.2-1 Present Conditions

A highlead logging operation was sampled and the data recorded (display 3.3-1)

Recorded elements are totaled and averaged. Slope and length of water travel are properly weighted to reflect the area in various disturbances. The buffer data pertains to the distance and slope between a given disturbance and the

from USDA SCS, West Tech Ctr, Portland OREGON, TECH NOTE #10 (1977)

functioning channel. These elements are used to develop a simple sediment delivery ratio. The cover factors are averaged and recorded.

In the example used for this discussion 22 percent of the transect paces fell on log paths, roads, or fire trails. All other hits were on forest duff. Elements are recorded in a simple way. Display 3.3-1.

Percent Slope and Length Feet

1. The percent area based on transect hits for each disturbance class is recorded in display 3.3-1. For log paths this is 5 + 3.7 = 8.7 percent.

2. Bare ground in this example is 5 + 3.0 + 5.3 = 13.3 or 13 percent.

3. Weighted averages of percent slope and lengths are developed for each disturbance class.

   Weighted % Slope = {(34)(8.7)+(5)(5.0)+(30)(8.3)}/22 = 26 percent

   Weighted Slope Length feet = {(133)(8.7)+(40)(5.0)+(55)(8.3)}/22 = 82 ft.

LS Factor - The slope length factor is provided in table format, tables 3.2-4, and 3.2-5, or figures 3.1-6 & 3.1-7.

For the example, display 3.3-1, the present slope and length were calculated to be 26 and 82 respectively. Using figure 3.1-5 the area for the sample is located in the Xeric moisture regime and Mesic and Thermic temperature zone requiring the use of table 3.2-5 for the estimate of LS. The LS factor is computed to be 4.1. Enter the LS into the erosion computation (see pages 8 and 9.

Cover Factor (C)

Type I effect - figure 3.1-1 percent protected ground for the whole operation is 100 less the percent bare ground. Enter bottom of figure with 100-13 = 87 and read 0.08.

Type II effect - figure 3.1-2. The Type II effect is the produce of rainfall energy intercepted by the canopy (REc) and the decimal percent bare ground minus 1.

{Type II = 1-(REc)(% Br. Gr.)}

1/ Percent canopy cover is 60 percent. Enter figure at bottom with 60 and read from 1 meter line 42 percent on right side of figure. Enter 0.42, the gross reduction in energy by the canopy (REc), in equation.

2/ Percent bare ground is thirteen hundredths and entered into the equation.

$$\text{Type II} = \{1-(0.42)(0.13)\} = 0.95$$

Type III effect - figure 3.1-3. Since this is a forest floor the forest duff curve is used. The root network was estimated in 70 percent. Enter with 70 at bottom of figure and read 0.13. Enter 0.13 into the equation.

The C factor is the product of Types I, II, and III effects. (See graphic description display 3.3-4.) C = (0.08(0.95)(0.13) = 0.01.

Additional C factors are available for consideration in table 3.2-1.

K Factor - The erodibility of the soil is taken from soil survey information, developed by the soil scientist on the project, or estimated using table 3.2-2. This table requires the use of a wetting bottle and the procedure outlined on display 3.3-2. For the example, use a K of 0.32.

R Factor - Where no R value charts are available, use the procedures outlined in Technical Note, Conservation Agronomy No. 32, dated September 1974 (Rev. March 1975), to compute the total R factor (R_T). For our example the R factor was taken from a map provided by the Oregon State Conservationist, Soil Conservation Service, figure 3.1-4. The R of 47 was entered into the Erosion Computation, page 14. It should be noted that if snowmelt adds to the water available for erosive activity, a snowmelt R_S must be added to the R to form a total R_T.

For forested lands there are few areas where R_S is a problem. These are isolated on those sites where concrete frost develops or other factors prevent the melt waters from percolating into the soil. Where this does occur it is suggested that the R_T be weighted for the site in proportion to its occurrence, or erosion and sediment calculations be kept separate.

The procedure for developing EI factors for individual storms is presented in the Appendix. A sample of the procedure is shown in display 3.3-3.

Erosion Estimate

Rate Per Acre

$$A = R_T KLSC$$

$$= (47)(0.32)(4.1)(0.01)$$

$$= 0.62 \text{ tons/acre/year}$$

For the 80-Acre Highlead Operation

$$A = (0.62)(80)$$

$$= 49.6 \text{ tons/year}$$

Sediment Yield Estimate

Where:

Sediment delivery ratio $= 1 - \{L / [50 + (4)(\% S)]\}$

$= 1 - \{200 / [50 + (4)(42)]\}$

$= 0.08$

L = Slope length of buffer strip to channel.

S = percent slope of the buffer strip.

Estimated Sediment Yield = (0.62)(0.08)

= 0.05 tons/acre/year

Sediment Yield for Highlead Operation

= (0.05)(80)

= 4.0 tons/year

The sediment yield estimated by this procedure takes the material only as far as a functioning channel. Routing sediment through the stream system is not considered. It should also be noted that permanent road, slide, gully, streambank, and channel sediments must be added where necessary to complete the sediment picture.

2.2-2 Future Conditions

Seven elements within the computation process allow for anticipated change. These are in order of their appearance in the USLE: K, L, S, C. The three remaining are the total acres of disturbance type, percent bare ground within the disturbed area, and the changes expected in the buffer widths.

The following elements in the example are adjusted for the new estimate:

Bareground: reduced from 13 to 9 percent by improved management.

Rootnet: increased from 70 to 91 percent by new plant growth.

Slope Length: all changes are due to improved management.

Logpaths from 133 to 107 feet - a better highlead setting

Road and Landings from 40 to 30 feet - increased drainage

Fire trails from 55 to 20 feet - by increasing waterbars

Percent Slope: No change anticipated.

Buffer: a 220-foot wide strip is set to assure there would be little or no sediment yield.

Introducing these changes then will give a new estimate of the erosion and sediment yield for this example as follows:

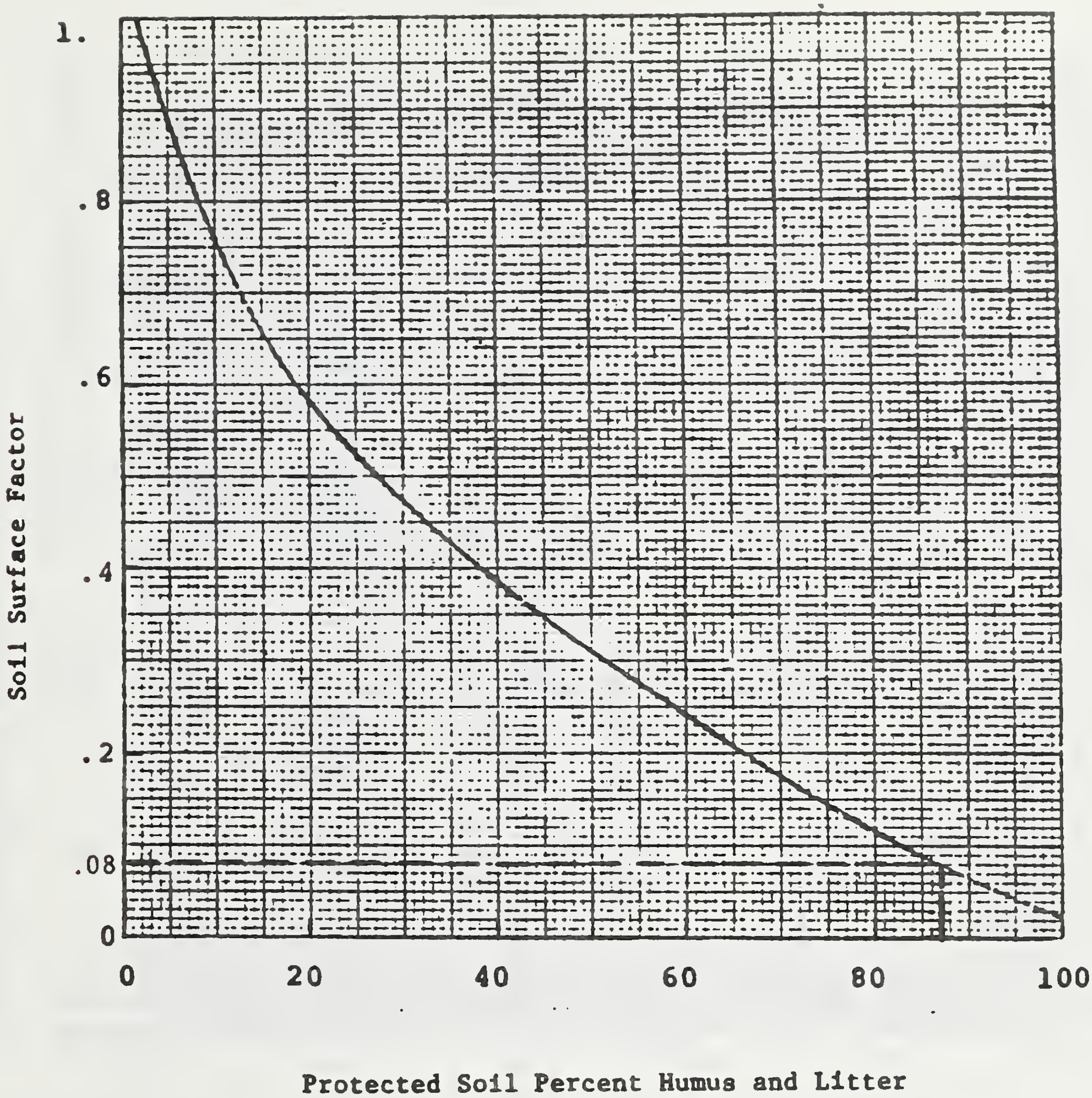


Figure 3.1-1

Cover in Direct Contact with the Soil Surface, Type I Effect

W.H. Wischmeier. Approximating the Erosion Equation's Factor C for Undisturbed Land Areas, USDA, Agricultural Research Service, Unpublished Report

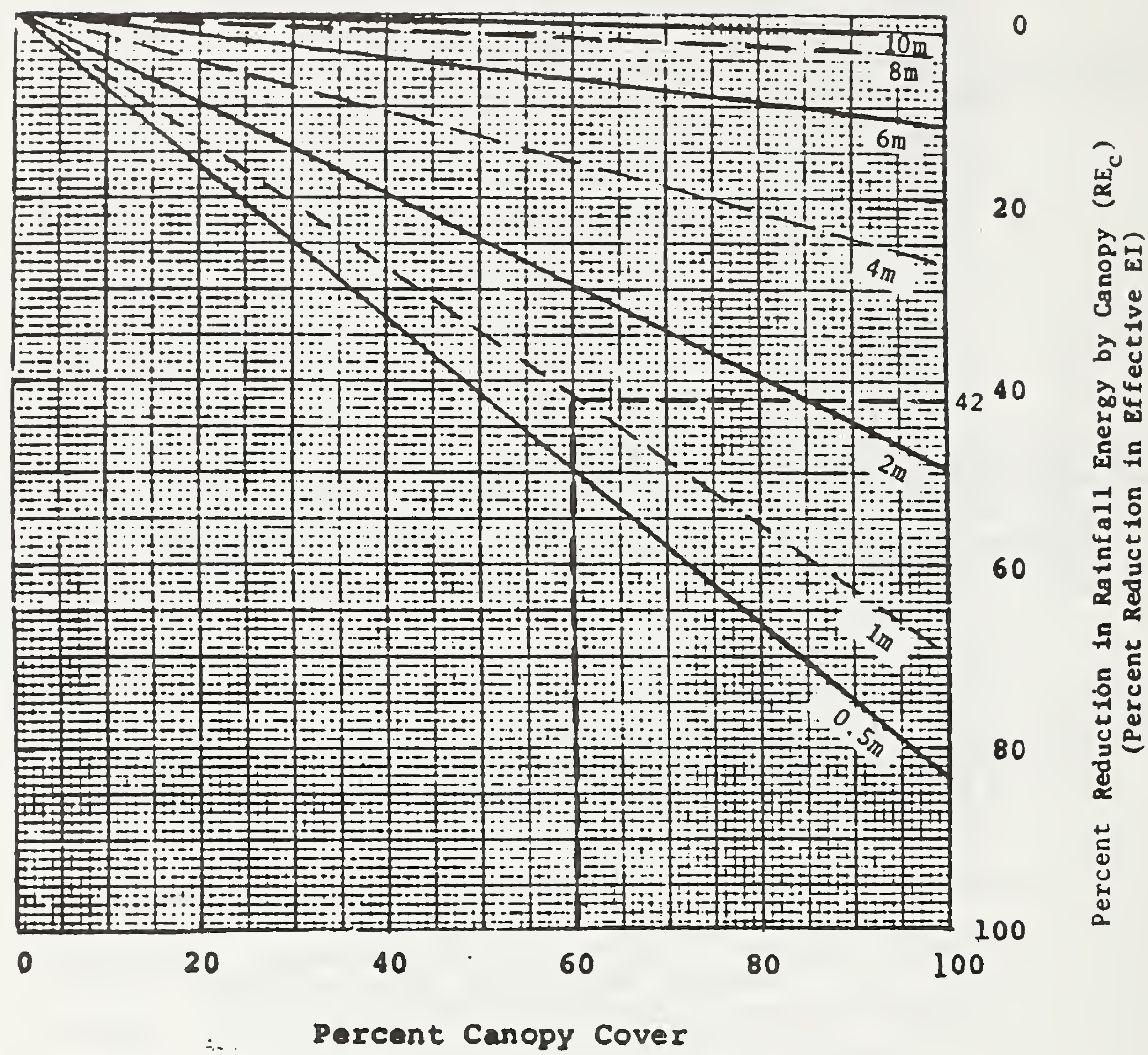


Figure 3.1-2

Reduction in Rainfall Energy (RE_c) by Effective Canopy Cover Above the Soil Surface

Adapted from W. H. Wischmeier, Approximating the Erosion Equation's Factor C for Undisturbed Land Areas, USDA Agricultural Research Service, Unpublished Report

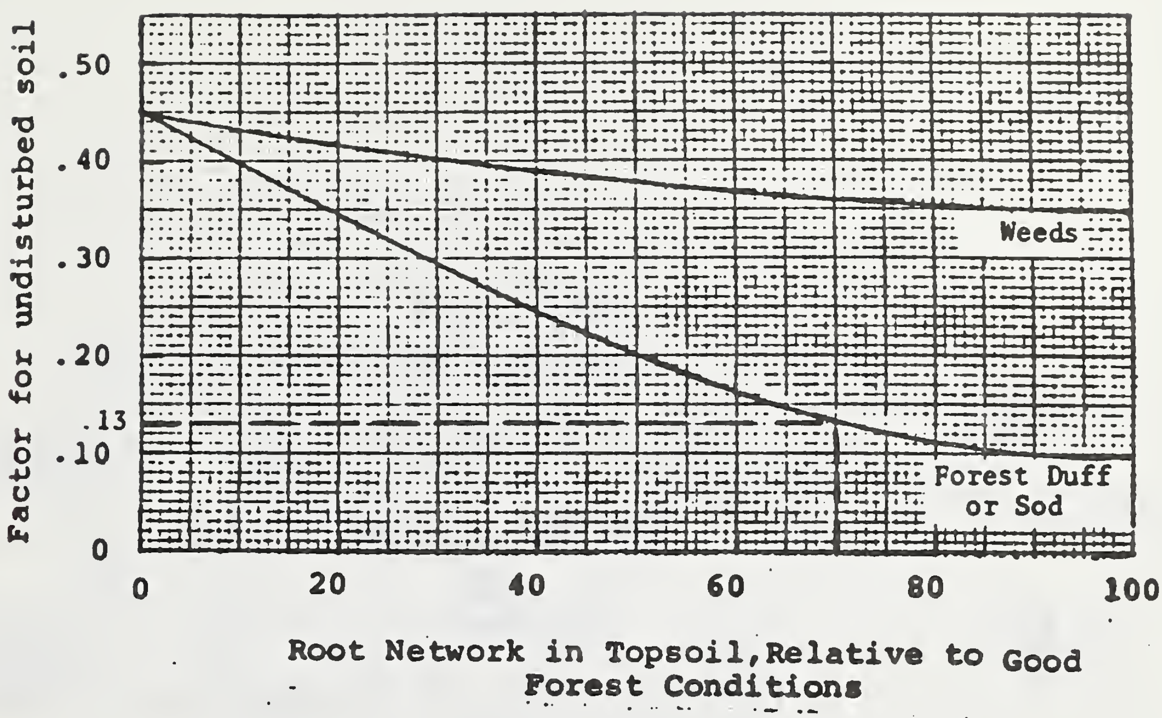


Figure 3.1-3

Effect of No Soil Disturbance for at Least 10 Years, Root Accumulation in the Upper Layer of Soil, and other Related Factors, Type III Effect

W.H. Wischmeier, Approximating the Erosion Equation's Factor C for Undisturbed Land Areas, USDA Agricultural Research Service, Unpublished Report

DISPLAY 3.3-4

EVALUATION OF C

TYPE I

87% PROT. GR.

.08

TYPE II = $[1 - (RE_C)(\text{BR. GRD.})]$

TOTAL RAINFALL ENERGY

60% CANOPY

(FROM FIG. 3.1-2 42 REDUCTION)

.13 BR. G. | .87 DUFF

$[1-(.42)(.13)] = .95$

TYPE III

70% FOREST ROOT

.13

$C = (.08)(.95)(.13) = .01$

NOTE: $(.42)(.13) = .05$ ENERGY REDUCTION

: ENERGY $= 1-(.05) = .95$

Table 3.2-2

GUIDE FOR ESTIMATING ERODIBILITY (K) VALUES

Soil Surface Texture 1/	Permeability			
	Very Slow	Slow	Mod. Slow, Moderate	Mod. Rapid, Rapid, Very Rapid
c, sic, sc 2/	0.37	0.32	0.28	0.24
scl, sicl, cl	0.43	0.37	0.32	0.28
sil, l, vfsl	0.49	0.43	0.37	0.32
fsl, sl	0.37	0.32	0.24	0.20
ls, s, lcs, cls	0.28	0.24	0.20	0.17 or .15

1/ Gravelly, channery, shaly, slaty, cherty, cobbly, or flaggy phases of these textures are normally reduced one or two classes in K value.

2/ C, Clay; Si, Silt; S, Sand; l, loam; vf, very fine; f, fine

REFERENCE: Soil Conservation Service, 1969, Hydrologic Group K and T Factors of Series Having Type Locations in the South Region: South Regional Technical Service Center, Fort Worth, Texas

LEGEND

Moisture Regime	Temperature Zones
Xeric	A-1 Mesic and frigid
	A-2 Cryic and frigid
	A-3 Mesic and thermic
	A-4 Mesic, thermic and hyperthermic
Ustic	B-1 Mesic and frigid
	B-2 Mesic and frigid
	B-3 Mesic, thermic and hyperthermic
Udic	C areas

Fig. 3.1-5 Soil Moisture-Soil Temperature Regimes

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

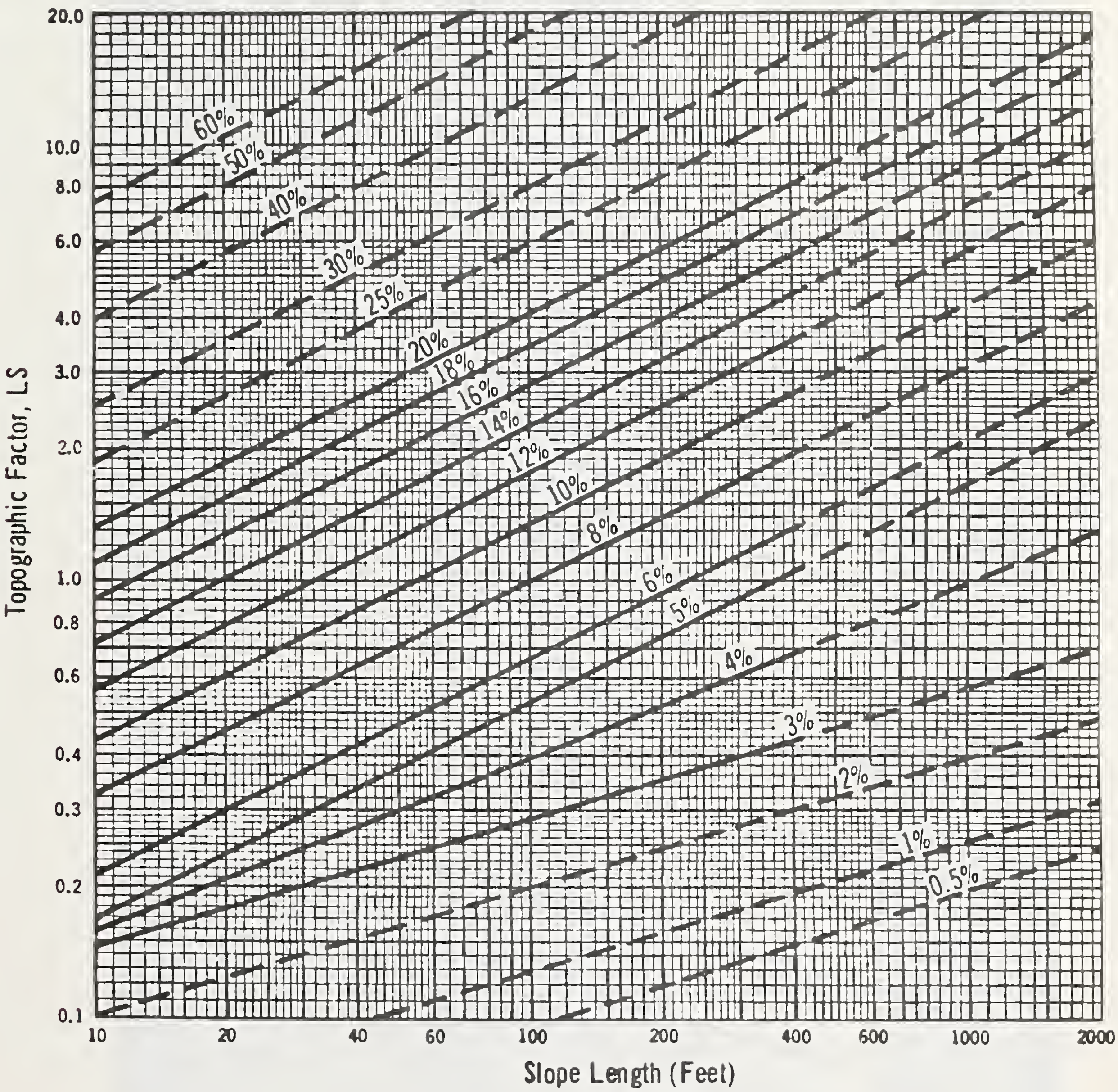
WEST TECHNICAL SERVICE CENTER AREA

SEPTEMBER 1977

50 0 50 100 150 200 250 300 MILES
SCALE 1:11,380,000

Figure 3.1-6 - Applicable to all Soil Moisture - Soil Temperature Regimes except A=3, and A-1 in WN, OR, and ID.

SLOPE-EFFECT CHART (Topographic Factor, LS)*



*The dashed lines represent estimates for slope dimensions beyond the range of lengths and steepnesses for which data are available. The curves were derived by the formula:

$$LS = \left(\frac{\lambda}{72.6}\right)^m \left(\frac{430x^2 + 30x + 0.43}{6.57415}\right)$$

where λ = field slope length in feet and m = 0.5 if s = 5% or greater, 0.4 if s = 4%, and 0.3 if s = 3% or less; and x = sin θ. θ is the angle of slope in degrees.

Figure 3.1-7

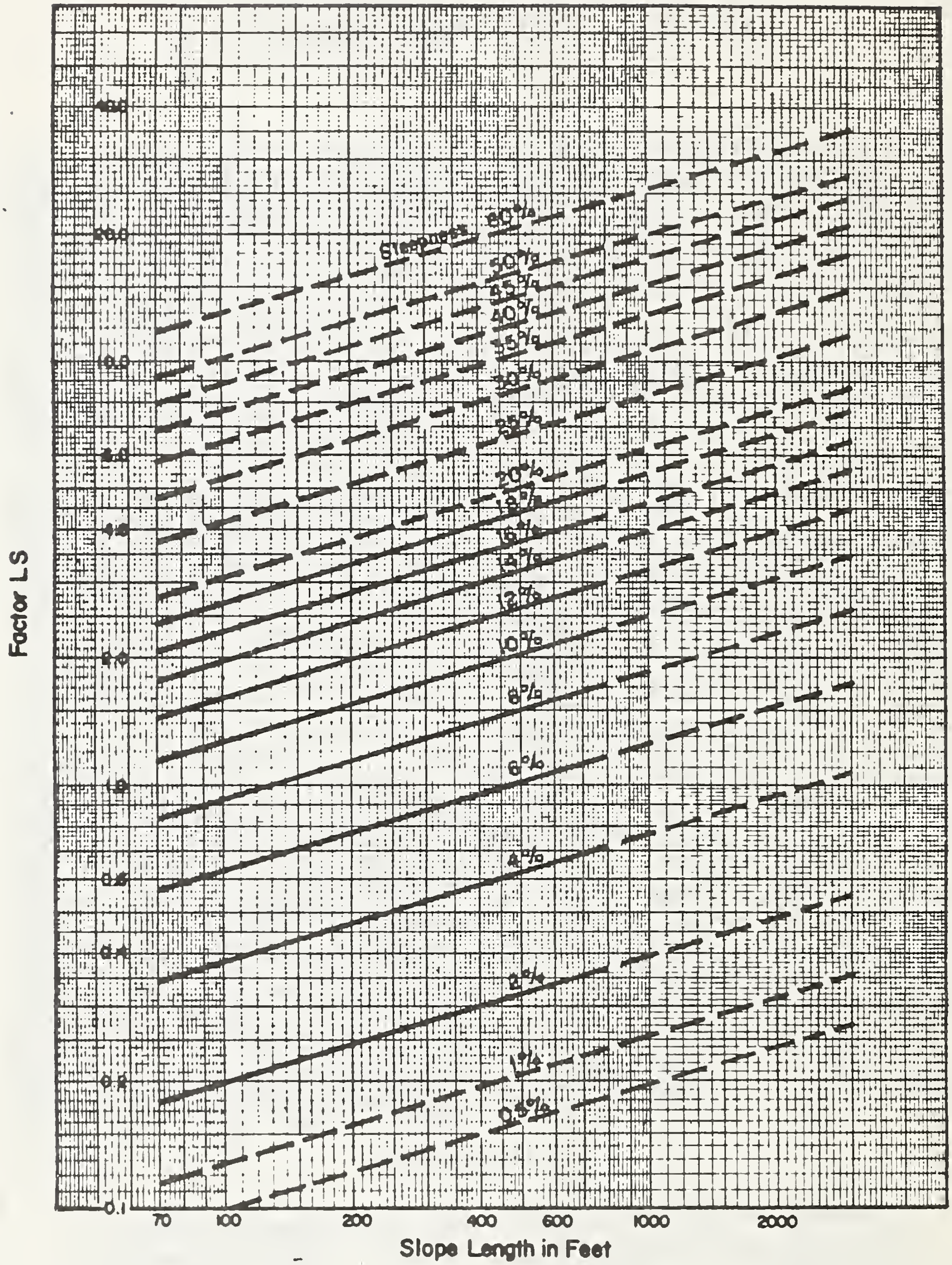


Figure 3.1-7 Applicable to Soil Moisture-Soil Temperature Regimes A-1 in WN, OR, and ID; and in A-3

Note: Dashed lines are extensions of LS Formulae beyond values tested in studies.

For slopes less than 9% $LS = \left(\frac{\ell}{72.6}\right)^{0.3} \left(\frac{0.43 + 0.30 + 0.043s^2}{6.613}\right)$

For slopes greater than 9% $LS = \left(\frac{\ell}{72.6}\right)^{0.3} \left(\frac{s}{9}\right)^{1.3}$

ℓ=length of slope
s=percent slope

HORSE CREEK ROAD CONSTRUCTION DETAILS

In 1978 and 1979 the roads to access the harvest units in the south facing subdrainages of the Main Fork Drainage were constructed. Four separate roads were constructed to totalling 7.343 miles. Figure 1 and Table 1 show the road locations and provide information on road length and road standard for each subdrainage.

There were two standards of roads constructed in these subdrainages and within each subdrainage the length of road is of a single standard. Standard 1 utilized road design criteria currently employed by the Nezperce National Forest. The objective of standard 1 design criteria is to provide for smooth traffic flow at a constant speed of 15 miles per hour. This necessitates careful consideration of alignment and curve radius. Horizontal and vertical alignment considered sight distance and grade breaks for relief of traffic flow, but did not consider grade breaks for relief of cut and fill slope height. The minimum curve radius was 110 feet and for curve widening, 400 feet. Subgrade, travelway, and ditch widths were 16, 12, and 3 feet, respectively.

This standard was applied to roads constructed in subdrainages 18, 16, 15, and 12. There were differences in the travelway, cut, and fill slope stabilization on roads in these three drainages. In drainages 18, 16, and 15 the travelway consists of 8 inches gravel and all cut and fill slopes were hydromulched, seeded and fertilized. Additionally, filter windrows of slash were placed on the lower portions of the fill slopes for at least 100 feet either side of a live water crossing.

In drainage 12 there was no travelway stabilization and no filter windrows at the live water crossings. Cut and fill slopes were not mulched or seeded.

Standard 2 design criteria does not consider smooth traffic flow, but rather attempts to minimize the cut and fill slope heights and "fit the terrain" to create a road with fewer erosion and drainage problems. The minimum curve radius was 50 feet and for curve widening 200 feet. Horizontal alignment provided for rolled grades for drainage relief and to minimize cut and fill slope heights. Subgrade, travelway and ditch widths were 15, 12, and 1 feet, respectively.

This standard was applied to roads constructed in drainages 14, 11, 10, and 8. In drainage 14 the travelway was asphalted and the cut and fill slopes were stabilized with a straw/asphalt tack mulch, seeded and fertilized. Filter windrows of slash were constructed at each live water crossing. In drainage 10 the travelway and cut slopes were not stabilized, nor were filter windrows constructed. Fill slopes were treated with seed and fertilizer, but were not mulched. In drainage 8, the travelway was stabilized with 8 inches of gravel, cuts and fills were seeded and fertilized and mulched with a straw/asphalt tack mulch. Straw bales were placed at the toe of the fill slopes for at least 100 feet on both sides of the stream crossing to impede soil movement to the stream.

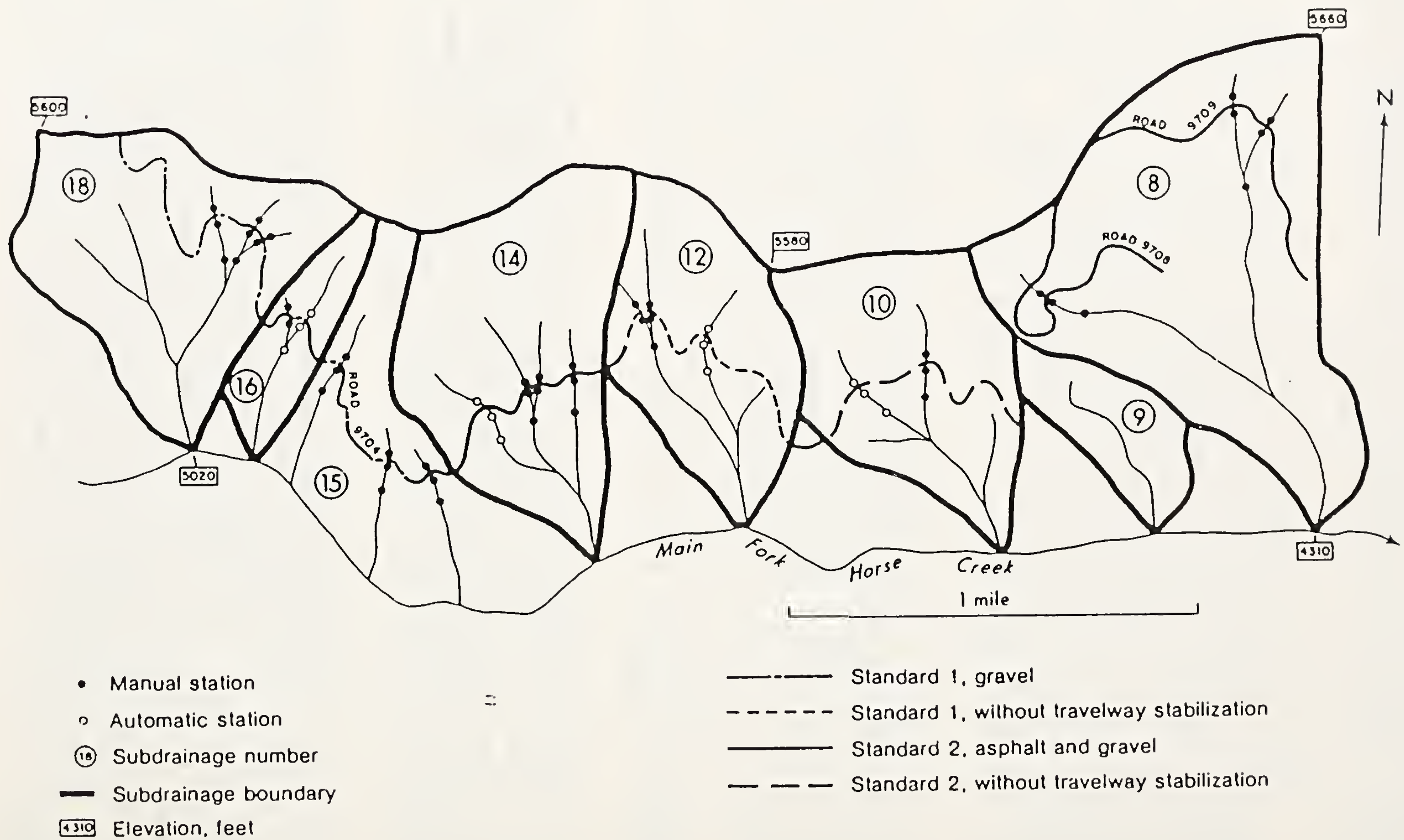


Figure 1. Road location and standard for the south facing drainages in the Main Fork of Horse Creek

Table 1.--Summary of standards by road number and drainage in the Horse Creek Administrative-Research Area.

Road Number	Drainage	Standard	Road Length (miles)	Road Density (miles/acre)
9704	18	1	0.944	0.0054
9704A	18	1	0.203	
9704	16	1	0.278	0.0040
9704	15	1	0.304	0.0040
9704	15	2	0.357	
9704	14	2	0.567	0.0039
9704	12	1	1.055	0.0050
9704	11	2	0.169	0.0027
9704	10	2	0.860	0.0052
9708	8	2	1.385	0.0071
9708	8	2	1.221	

Construction of the roads in drainages 18, 16, and portions of 15, and 8 were completed in 1978. In 1979 roads were constructed in the remainder of the drainages.

Additional specifications on the road standards and specific treatments are presented in the "Road Plans" prepared by the Nezperce National Forest and in the "Prospects of the Road Engineering Research" prepared by the Intermountain Forest and Range Experiment Station. Differences between standards or between the roads in specific drainages are discussed in subsequent sections of the report, where applicable.

United States
Department of
Agriculture

Forest Service

**Intermountain
Forest and Range
Experiment Station
Ogden, UT 84401**

Research Note
INT-335

November 1983

Construction Cost and Erosion Control Effectiveness of Filter Windrows on Fill Slopes

**Michael J. Cook
John G. King**[1]

ABSTRACT

Sediment barriers of slash were designed and constructed on the fill slopes of newly constructed roads. These barriers called filter windrows were located in the vicinity of stream crossings in an attempt to prevent eroded fill material from entering the stream. The contractor was able to construct windrows at a rate of 170 ft/h (52 m/h), using a track-mounted Caterpillar 235 hydraulic pull shovel (a large backhoe). The cost of this fill slope treatment was $59 per 100 feet (30 m) of windrowed slope. A conservative estimate of the sediment trapping efficiency of the windrows is 75 to 85 percent, based on measurements of fill slope erosion on windrowed versus non windrowed slopes. The results indicate that the construction of filter windrows on fill slopes is a relatively inexpensive and a very effective treatment for preventing eroded material from entering adjacent streams. Filter windrows can be constructed simultaneously with road construction, providing immediate protection of the water resources.

KEYWORDS: road erosion, sedimentation, erosion control

Surface erosion from roads, especially fill slopes, is greatest during the first year following construction. Megahan's (1972) 6-year study of sediment production from a logging road in the Idaho Batholith revealed that 83.8 percent of the total surface erosion occurred during the first year following construction, with an additional 9.4 percent occurring during the second year. Another study of fill slope erosion in the Horse Creek drainage of north-central Idaho (USDA 1981) reported that 56 percent of the erosion over a 2-year period occurred in the first 2.5 months after construction. Subsequent reduction of the surface erosion rate is due to vegetation establishment and armoring of the slopes.

Slope stabilization measures are often delayed until the autumn following the construction season. Thus, the newly exposed slopes are subject to erosion during convective summer storms. Treatments of seed, fertilizer, and mulch are not completely effective until after seed germination and growth the following spring. Other techniques that incorporate the use of netting or mats are expensive.

The objective of this study was to demonstrate a sediment control technique that utilizes natural materials, provides immediate protection to live streams, requires no additional disturbance width, is esthetically acceptable, and is inexpensive. The technique is to construct sediment barriers, called filter windrows, on the fill slopes adjacent to streams. In this study, filter windrows were constructed with logging slash, long known as a deterrent to sediment movement and readily available from the right-of-way clearing operation. Fill slope erosion was monitored on windrowed and nonwindrowed slopes to quantify the technique's effectiveness.

SITE DESCRIPTION

This project was undertaken in the Horse Creek Administrative-Research Study Area, located in the Nezperce National Forest approximately 35 miles (56 km) east of Grangeville, Idaho (fig. 1). Elevations in the 7,700-acre (3 116-ha) watershed range from 4,110 feet (1 253 m) to 6,025 feet (1 836 m). Grand fir (*Abies grandis*) is the major tree species. Other species include Douglas-fir (*Pseudotsuga menziesii*), western redcedar (*Thuja plicata*), Englemann spruce (*Picea englemannii*), subalpine fir (*Abies lasiocarpa*), and Pacific yew (*Taxus brevifolia*).

[1]Michael J. Cook is a forest engineer with the Nezperce National Forest, Grangeville, Idaho; John G. King is a hydrologist located at Intermountain Station's Forestry Sciences Laboratory, Moscow, Idaho.

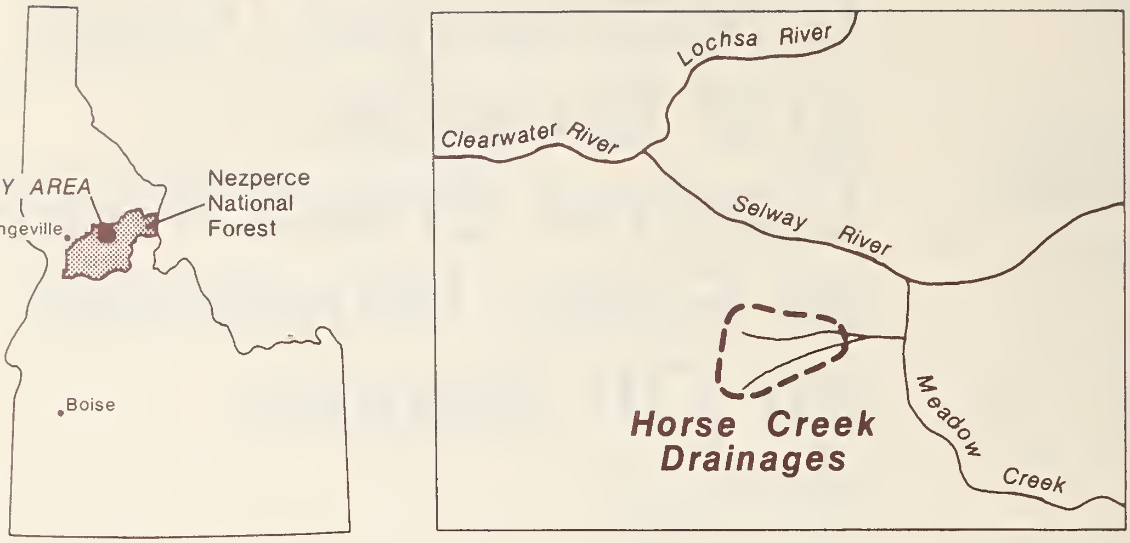


Figure 1.—Location of the Horse Creek Administrative-Research Area.

The area's climate is influenced by modified maritime air masses from the Pacific Ocean. Average annual precipitation is 48 inches (122 cm), 60 to 70 percent of which occurs as snow. The wettest month is January and the driest month is July. Summer convective storms occur from late June through mid-September. The maximum monthly average temperature of 59° F (15° C) occurs in August and the minimum of 17° F (-8° C) occurs in January. Winter temperatures are generally moderate and winter melt is common.

Four major soil types occur in the study area. In order of the percentage of the area they occupy, they are: loessial silt loams, 10 to 30 inches thick (25 to 76 cm); loams to sandy loams, 12 to 30 inches thick (30 to 76 cm); loessial silt loams, 2 to 4 feet thick (61 to 122 cm), overlaying hard mica schist and quartzitic gneisses; and loessial silt loams, 6 to 18 inches thick (15 to 46 cm), overlaying micaeous loams (USDA 1976). The road was constructed on an SM type (silty sand), often grading to a GM type (silty gravels) or a GW type (gravel-sand mixture) at a depth of about 2 feet (60 cm), based on the Unified Soil Classification System (Wotring 1981).

The climate and topography are typical of much of northern Idaho, eastern Washington, and western Montana. Steep slopes and erodible soils present a challenge to land managers concerned with protecting streams, spawning areas, and the total forest ecosystem.

CONSTRUCTION PHASE

Planning

Field work consisted of staking areas for windrow construction, determining the proximity of suitable slash, and selecting stockpile sites. Generally, the entire length of fill slope that could contribute directly to streams was designated for windrow construction. The average length of windrows on the project was 250 feet (76 m), with a range of 70 to 450 feet (21 to 137 m).

Project specifications and a drawing were prepared for inclusion in the road construction contract (appendix). The type of windrow selected was one that would require no additional clearing, would provide a low profile conforming to the fill slope, and would utilize readily available materials.

Construction

Construction was accomplished in two phases. First, during clearing and pioneering at designated sites, suitable material was stockpiled at the upper edge of the staked clearing limits. This did not require any additional time. Coordination between the contractor and engineer insured that stockpile areas would not interfere with planned work and would be conveniently located for later use. Location of stockpiles, either above or below the clearing limits, can easily be modified to accommodate many different clearing operations and contractor requirements.

Second, windrows were constructed by moving a cull log from the stockpile, placing it in position at the toe of the fill, and anchoring it into place against stumps, rocks, or trees with the pull shovel (fig. 2). Stockpiled slash was then placed on the fill slope above the cull log (fig. 3) (see appendix for dimensions). The windrow was compacted by tamping the slash with the shovel. This produced a relatively dense windrow embedded in the top 6 inches (15 cm) of the fill surface. It is important that the slash be embedded to prevent flow of material through or under the slash.

All work in the second phase was accomplished from the road subgrade as fill construction progressed, using a track-mounted Caterpillar 235 hydraulic pull shovel (a large backhoe) with a 360 degree swing. Equipment was the same as that used during the clearing and stockpiling operation. Manual laborers were not required.

All fill slopes were constructed with a 1½:1 slope. The road travelway was stabilized with an 8-inch (20-cm) lift of gravel. In the fall following construction, the fill slopes were seeded, hydromulched, and fertilized.

Figure 2.—Placement of the cull log at the toe of the fill slope.

Figure 3.—Filter windrow 2 years after construction.

Construction Monitoring

Construction was monitored during the clearing and pioneering operation and during filter windrow construction. A total of 1,190 feet (363 m) of windrows were constructed at five stream crossings. All windrows were constructed without interruption.

The total equipment time for construction of all filter windrows was 7.0 hours. Included in equipment time were the equipment move-in and move-out time, the equipment production time, and the average equipment travel speed. Equipment was walked from other work within the project at an average speed of 5 mi/h (8 km/h). Move-in and move-out times were approximately 0.5 hours each. The pull shovel was able to construct 200 lineal feet (61 m) of windrow per hour once at the site. This production time includes movement of cull logs and slash from stockpiles, placement on the slopes, and compaction. Average distance from stockpile to windrow was 350 feet (107 m) and between windrow locations it was 0.2 mile (0.3 km). No equipment breakdowns were encountered. Times will vary with the equipment used and the site. The production rate for windrow construction on this project, considering travel time to the sites, was 1,190 feet (363 m) in 7.0 hours or 170 ft/h (52 m/h).

WINDROW PERFORMANCE

The effectiveness of the filter windrows in preventing eroded material from leaving the fill slopes was measured in two different ways. The first method involved placement of 4-foot-long (1.22-m) troughs, with a capacity of 1 ft^3 (0.03 m^3), immediately below the windrows to collect eroded material transported through or over the windrows. In the second method, the volumes of all rills and gullies in the fill slopes above the windrows and transport distance below the windrows, if any, were measured.

Collection Troughs

Fifteen troughs were installed along the 1,190 feet (363 m) of windrowed fill slopes in 1978, within 1 week following windrow construction. Five troughs were placed below fills with vertical heights of less than 10 feet (3 m), or class 1 slopes. Ten troughs were placed below fills ranging in height from 10 to 20 feet (3 to 6 m), or class 2 slopes. The material in the troughs was removed and volumetrically measured, with an estimated measurement error of ± 5 percent, following all major rain storms, once each late fall, and once each spring from July 1978 through August 1981. The volumes of material in the troughs were averaged for the two height categories of fill slopes and are expressed as ft^3/100 ft of road (m^3/1 000 m).

The total amount of eroded material transported through the windrows during the 3 years after road construction was 0.325 ft^3/100 ft (0.302 m^3/1 000 m) for class 1 slopes and 0.650 ft^3/100 ft (0.603 m^3/1 000 m) for class 2 slopes (fig. 4). Erosion of fill slopes not protected with filter windrows for this same period was 35.85 ft^3/100 ft (33.29 m^3/1 000 m) for class 1 slopes and 64.30 ft^3/100 ft (59.70 m^3/1 000 m) for class 2 slopes (fig. 4). Thus, approximately 99 percent of the eroded fill material was deposited within the windrow. Over a 3-year period the windrows reduced the amount of sediment leaving the fill slopes by 163 ft^3 (4.6 m^3) for class 1 slopes and 465 ft^3 (13.2 m^3) for class 2 slopes.

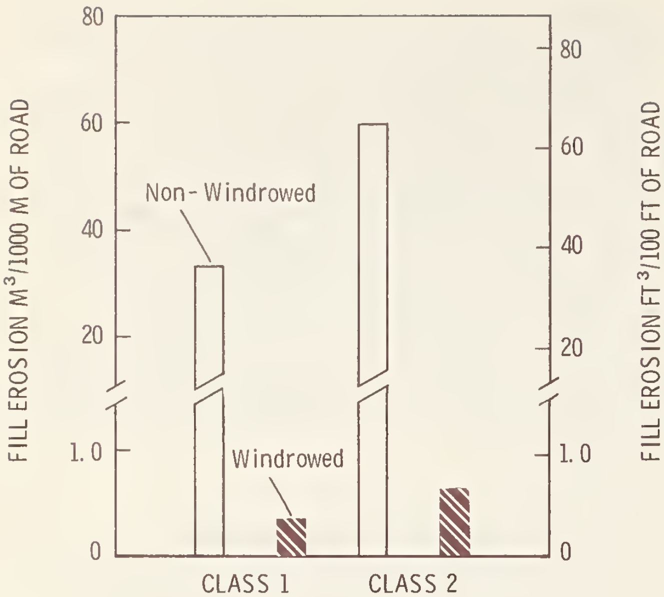


Figure 4.—Fill erosion volumes for windrowed and nonwindrowed slopes by vertical height class during the 3 years following construction.

Gully Surveys

Surveys of the rills and gullies formed in the fill slopes above the filter windrows were made each spring and fall for 3 years following road construction. Measurements of average top width, bottom width, and length of the rills were used to determine volumes, with an estimated measurement error of ±15 percent. In addition, the void volumes of material displaced by slumping above the windrows were measured. If material was transported either through or over the windrow, the downslope travel distance was measured.

The total amount of eroded material transported to all the windrows as rill and gully erosion was 187.0 ft^3 (5.3 m^3) for the 3-year period. An additional 115.5 ft^3 (3.27 m^3) of material was displaced by slumping, but the fraction of this slumped material reaching the windrows was not determined.

Figure 5 shows the cumulative rill and gully erosion above the filter windrows. The rate of erosion decreased rapidly with time. After 2 years the slopes were well-vegetated and the majority of the rills and gullies were stabilized. A survey in the summer of 1981 indicated that only 3 of the 36 gullies were still active and that they were beginning to stabilize.

In the 3 years since windrow construction there have been only seven instances when eroded fill slope material was transported past the windrows. Material reached the streams in only three of these instances. Windrow failures were usually associated with slumping, which occurred in late spring when the fill slopes were saturated with snowmelt water. In several cases, the windrows were still partially covered with snow and the slumped material moved over the windrow. In other cases, the subsequent rill erosion in slumped material was transported through the windrows.

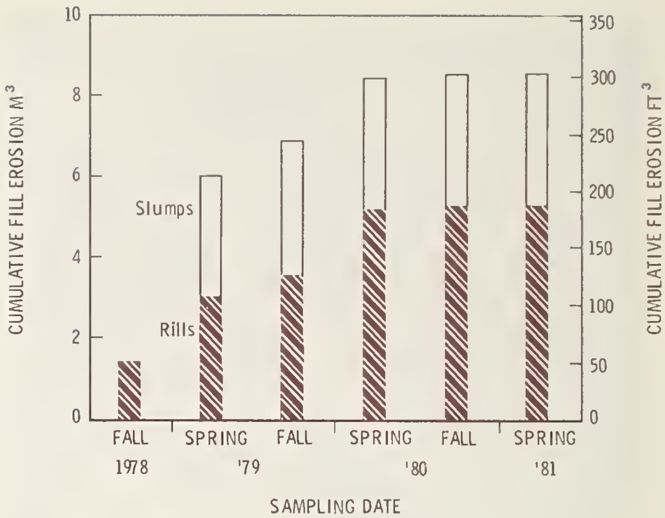


Figure 5.—Cumulative rill and slump erosion of the fills above the filter windrows for the 3 years following construction.

The windrows were effective in reducing downslope transport distance even when they were breached because only a small fraction of the sediment passed through the windrow. Average transport distance below the windrows was 3.8 feet (1.2 m) while average transport distance below unprotected fill slopes was 24.2 feet (7.4 m) if slumping had not occurred and 41.4 feet (12.6 m) below slumped areas of fill.

An accurate determination of the trapping efficiency of the windrows using the rill volume data is not possible because there was no measure of volumes being transported through the windrows. A conservative estimate of trapping efficiency is 75 to 85 percent if the assumption is made that 50 percent of volume was transported through the windrow at each breach.

SUMMARY

The contractor was able to construct 170 feet (52 m) of filter windrow per hour at a cost of $59 per 100 feet (30 m) of windrow. Over the 3 years since construction the windrows have been very effective (75 to 85 percent) in preventing material from leaving fill slopes. The cost of preventing 628 ft^3 (17.8 m^3) of sediment from leaving the slopes was $700 ($39.33/m^3). Total costs will vary with the abundance of suitable materials, travel distances between locations, and care taken in locating and flagging slash stockpiles.

The use of filter windrows on fill slopes at stream crossings is an inexpensive and effective method for minimizing delivery of eroded fill material to streams. With increasing concern over maintaining desirable habitats for trout and anadromous fish, the authors recommend this practice as one means of preventing sediment from entering streams at road crossings. Windrows can be constructed shortly after road pioneering to provide immediate protection to the streams.

Other management considerations relative to the use of filter windrows include fire hazard, the possibility of insect infestation, wildlife movement patterns, and

esthetics. As constructed in Horse Creek, big game can easily cross the windrows. If windrows are constructed continuously along the length of the road, perhaps not only for reducing erosion but also for disposing of part of the slash produced during clearing, then these other considerations become more important.

The vertical heights of the windrowed fill slopes ranged from 5 to 20 feet (1.5 to 6.1 m). The effectiveness of windrows on fill slopes with higher erosion rates—for example, on steeper or higher fills, more erosive soils, or sites where revegetation may be slower—may be less than reported for this study.

Eventual decay and weakening of windrows may allow downslope movement of stored sediment in subsequent years if stabilization by revegetation has not occurred. In Horse Creek, virtually all of the fills that were seeded and mulched have excellent vegetative cover. The authors believe that subsequent gradual decay of the slash in the windrows will not cause a significant release of stored sediment for downslope movement. These windrowed slopes will be observed for the next few years to evaluate their long-term performance.

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APPENDIX
SPECIAL PROJECT SPECIFICATIONS
SECTION 201A - FILTER WINDROW

Description

201A.01 - It is the intent of this specification to provide for the construction of a windrow of logging slash that will act as a sediment trap or filter to reduce erosion effects from newly constructed fill slopes.

Materials

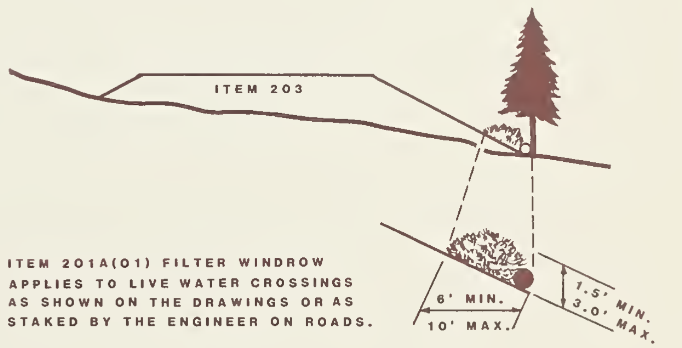
201A.02 - Suitable slash shall be conserved from Item 201(01) Clearing and Grubbing, and stockpiled at approved sites. Slash to be conserved shall consist of tops, limbs, and brush not to exceed 6 inches in diameter, and 12 feet in length. Stumps and root wads shall not be included.

Construction Requirements

201A.03 - Logs of not less than 18-inch diameter shall be placed on the fill slope immediately above and parallel to the toe for the windrow to catch against. Reasonably sound cull logs may be used if available. They shall be firmly anchored against undisturbed stumps, rocks, or trees, or as otherwise directed by the Contracting Officer's Representative (COR).

All material in the windrow shall be placed to form a neat, compact, and uniform pile. Windrows shall be placed so that they do not interfere with the functioning of drainage structures or block stream channels.

Windrows shall be constructed only in locations staked by the COR, on the fill slope immediately above the toe as shown on the drawings.



FILTER WINDROW DIMENSIONS

Methods of Measurement

201A.04 - The amount to be paid for shall be the number of linear feet of windrow, as measured along the toe of the fill, completed and accepted.

Basis of Payment

201A.05 - The accepted quantities of windrow, determined as provided above, will be paid for at the contract unit price, which price and payment will be considered full compensation for the work prescribed in this item. Payment will be made under:

Pay item	Pay unit
201A(01) Filter Windrow..................................	Linear foot

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The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

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XIV.

REDUCING EROSIONAL IMPACTS OF ROADS

by

Walter F. Megahan
Intermountain Forest and Range
Experiment Station 1/

1. INTRODUCTION

Accelerated erosion may take place following road construction on forested lands. Some possible causes include: (a) removal or reduction of protective cover; (b) destruction or impairment of natural soil structure and fertility; (c) increased slope gradients created by construction of cut and fill slopes; (d) decreased infiltration rates on parts of the road; (e) interception of subsurface flow by the road cut slope; (f) decreased shear strength, increased shear stress, or both, on cut and fill slopes, and (g) concentration of generated and intercepted water.

Numerous reports substantiate the fact that road construction can accelerate erosion on forested lands (1, 2, 4, 6, 9, 14, 15, 18, 19, 20, 22, 24). Experience by FAO in developing countries has often shown that roads are the major source of erosion. As might be expected, effects vary considerably depending on the geologic, climatic, landform, soil, and vegetation properties of the area or country in question and upon the care taken to reduce erosion in all phases of the road development project. Roads constructed on glaciated, metamorphic parent materials in Colorado, for example, exhibited slight accelerated on-site erosion, but no significant increases in sediment yields were detected downstream (14). In contrast, construction of low standard, temporary logging roads on high erosion hazard granitic slopes in Idaho greatly accelerated on-site surface and mass erosion, causing downstream sediment yields to increase an average of over 45 times (from 8.8 to 396 metric tons/km^2/yr) for a 6-year study period (19).

The impacts of road erosion are many. The most direct is to the road itself; excessive erosion can, and often does inhibit road use or even make the road impassable until restored, often at great expense. Less obvious, but often more important, is the movement of eroded material off the site. This can cause sedimentation which may create excessive damage to downstream cultural and ecological values.

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Table 1 - Effect of harvest system and silvicultural practices on the percent area disturbed by road construction (reference 25).

Logging system - Silvicultural system	Logged area bared by road construction	Location	Reference
	%		
Jammer 1/ - Group selection	25-30	Idaho	(19)
High lead 2/ - Clearcut	6.2	Oregon	(26)
Skyline 3/ - Clearcut	2.0	Oregon	(3)
Helicopter 4/ - Clearcut	1.2	-	-

1/ Jammer - a small, truck-mounted skidder-loader - maximum reach about 60 m.

2/ High lead - a cable system that drags logs to the loading area - maximum reach about 200 m.

3/ Skyline - a cable system that suspends logs during transport to the loading area - maximum reach about 800 m.

4/ Estimated by Virgil W. Binkley, Pacific Northwest Region, U.S. Forest Service, Portland Oreg., based on a maximum flying distance of about 1.5 kilometers.

2. EROSION PROCESSES

Recognition of the type of erosion occurring on an area and knowledge of factors controlling erosion are important in avoiding problem areas and in designing control measures. Erosion can be broadly classified into two types - mass erosion and surface erosion. Mass erosion includes all erosion where particles tend to move en masse primarily under the influence of gravity forces. It generally includes various types of landslides plus nonrainfall associated erosion (dry creep). Surface erosion is defined as movement of individual soil particles by forces other than gravity alone such as overland flow of water and raindrop impact. Here, dry creep will be considered a surface erosion process because many soil stabilization measures designed to control surface erosion are also effective in controlling dry creep.

Surface erosion is a function of three factors: (a) the magnitude of forces available (wind, raindrop splash, overland flow, etc.); (b) the inherent erosion hazard at the site in question (soil detachability characteristics, slope gradient, etc.); and (c) the amount of material available to protect the soil surface (vegetation, litter, mulches, etc.). Mass erosion is controlled by the balance between the shear strength and the shear stress within the soil or fill material at the site in question; as long as shear strength exceeds shear stress, the site remains stable.

3. BASIC PRINCIPLES

Fortunately, the erosional impacts of road construction need not be passively accepted; there are a variety of practices available to reduce impacts. These can be summarized as four basic principles:

(1) Minimize the amount of disturbance caused by road construction by: (a) controlling the total mileage of roads; and (b) by reducing the area of disturbance on the roads that are built.

(2) Avoid construction in high erosion hazard areas.

(3) Minimize erosion on areas that are disturbed by road construction by a variety of practices designed to reduce erosion.

(4) Minimize the off-site impacts of erosion.

All four factors must be weighed to reduce total erosional impacts. This is important because stress on individual factors may not meet this goal. For example, a shorter road may have to be lengthened to avoid high erosion hazards. In this case, total erosional impacts may be minimized although the area disturbed is increased. Erosion control practices are certainly beneficial and considerable effort has been and should be devoted to their development and implementation. However, prevention, rather than control, usually is by far the most efficient means to reduce erosional impacts. Prevention can have an added benefit by avoiding possible irreparable damages or costly repairs that may exceed original construction costs.

<u>The first basic principle</u> emphasizes measures designed for erosion prevention rather than control. Minimizing road mileage and areas of disturbance help reduce erosional impacts considerably. This is particularly true on forested lands where the total length of road required is often regulated by the distance capabilities of logging systems and the silvicultural practices prescribed for the timber stands (Table 1).

Reductions in the area disturbed by road construction can also be made by careful road location and design. For example, use of flexible horizontal and vertical alignment standards during road location to avoid steep slopes can decrease the width of area disturbed considerably. To illustrate, total width of disturbance by a road 4 m wide

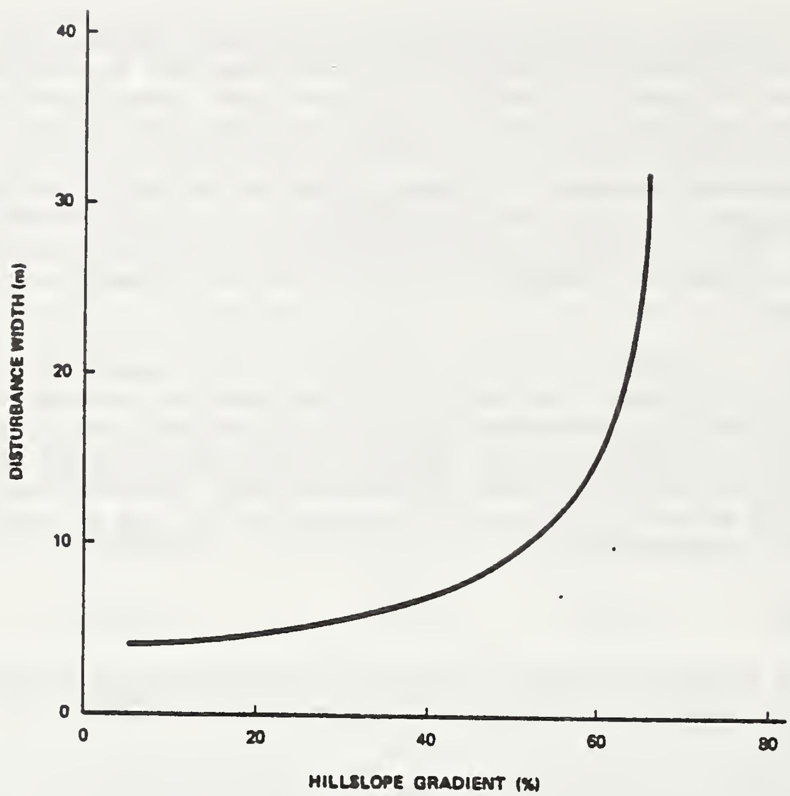

Figure 1. Width of disturbance (projected to a horizontal plane) caused by road construction as a function of hillslope gradient. Assumptions: road width, 4 m; fill slope gradient, 67% (1.5:1); cut slope gradient, 200% (0.5:1); volume of material removed from cut = volume of material in fill ("balanced construction").

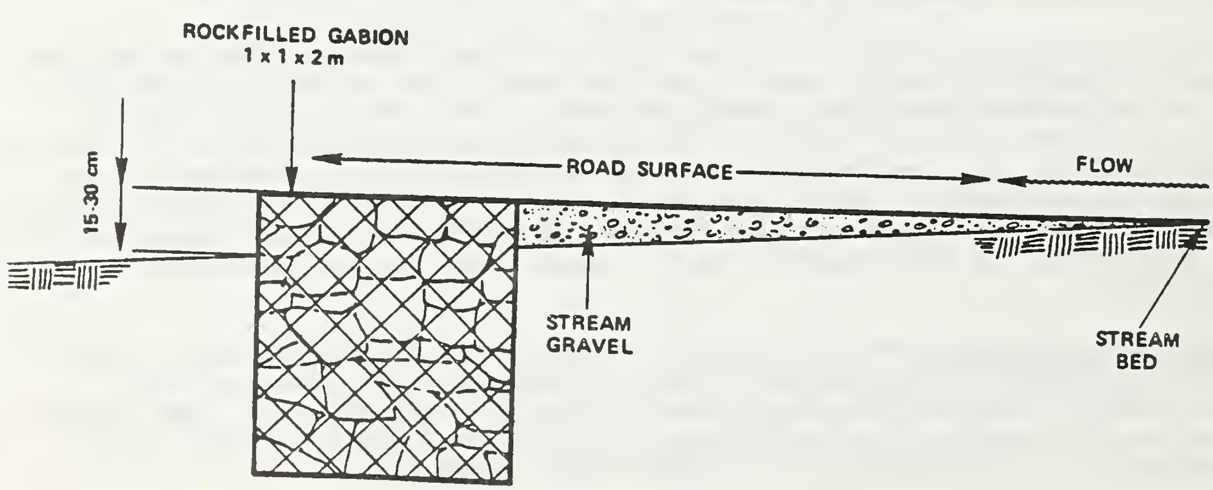

Figure 2. Ford construction stabilized by gabions placed on the downstream end.

increases from about 7 m on a 40% slope to 16 m on a 60% slope; on a 65% slope the width increases to 32 m (Fig. 1). For a given slope, additional reductions in area disturbed can be made by minimizing road and ditch width and by maximizing the gradient of cut and fill slopes (assuming the steeper slopes do not increase other erosion hazards).

The second basic principle for reducing road erosion impacts is another matter of prevention rather than control and consists simply of avoiding high erosion hazard areas. Examples of serious erosion problems caused by road construction in high erosion hazard areas are common, especially where landslide hazards are high. Here even minor location changes of 10 or 20 m may eliminate a major erosion problem. Usually, problems of this type arise from adoption of, and strict adherence to, traditionally accepted road standards (e.g., alignment standards for speed purposes) rather than providing some flexibility in standards to allow the road location to be adjusted to the site properties of the particular landscape in question.

The third basic principle is to reduce erosion on the areas that are distrubed by road construction. This is the traditional approach using a multitude of practices to help reduce erosion. Successful design of erosion control practices requires considerable knowledge of erosion processes, including the major type of erosion that is occurring and the individual factors that control erosion. To illustrate, little benefit results from attempting to stop mass erosion by mulching or surface erosion by installing subsurface drains. Likewise, mulching a road fill slope may have little value if improper design, failure of the road drainage system, or both, cause large quantities of water to flow over the fill.

The fourth basic principle for reducing erosional impacts is to minimize the off-site impacts of erosion that does occur. Essentially this amounts to reducing sediment delivery to stream channels by: (a) keeping disturbed areas as far from channels as possible, (b) providing a maximum of obstructions to catch and retain sediment before it reaches the drainage system, and (c) recognizing that the efficiency of a downslope area to deliver sediment varies considerably depending upon its form and structure.

4. GUIDELINES FOR REDUCING EROSIONAL IMPACTS OF ROADS

These guidelines are based upon the four basic principles which have been described above. They are presented in the context of the entire road development process proceeding from broad land use planning through road location, design, construction, maintenance, and closure. Presentation in this manner is not intended to restrict the guidelines to those higher standard roads receiving such formal step-by-step development. To the contrary, the basic erosion control principles apply to any road development and should be used throughout the development process regardless of the intended purpose or standard of the road.

The guidelines are not all inclusive, but rather are based upon concepts and techniques that have been applied in the temperate climates of the United States. They were developed from experience and research mostly in mountainous terrain. Many of the principles and procedures in this paper will be useful in other areas; however, modifications will undoubtedly be needed to accommodate unique site conditions found in a particular location. Therefore, it is important to verify applicability with local experts (e.g., engineers, land use planners, soil scientists, hydrologists, foresters, geologists) before applying the guidelines.

Much of the material presented here was abstracted from references (7), (10), (11), (12), (13), (21), (28), (29), (30), (31), (32), (33), (34), (35), (36), (37), and (38). The author acknowledges the excellent work of the various authors and institutions and recommends the original references for more in-depth consideration. Undoubtedly, many other excellent references have been developed and should be used where applicable.

5. LAND USE PLANNING

Land use planning with respect to road construction simply means anticipating the present and future uses of the transportation system to assure a maximum of service with a minimum of monetary and erosional costs. The objective of this phase of the road development process is to establish specific objectives and prescriptions for road development along with the broad location needs. This must be a coordinated effort among the land manager, road engineer, forester, geologist, soil scientist, and others who recognize specific problems and needs and recommend alternatives or solutions.

Land use planning is an important factor governing the total area disturbed by road construction. It is particularly important on forested lands where the total mileage of roads constructed is closely related to the timber harvest systems and silvicultural practices prescribed. Harvesting methods also affect the area of disturbance because width and alignment requirements vary with the type of practice used. Additional decisions related to all anticipated traffic, operating speeds, and safety requirements should be made at this time. All of these influence road width and alignment, which affect area of disturbance.

Future as well as present needs must be considered during the land use planning phase. This will help to avoid situations where the road is inadequate for future needs as, for example, in timbered areas where the road network is improperly located for second or third cuts.

The land use planning phase is the time to evaluate environmental and economic trade-offs. This should set the stage for the remainder of the road development process. If an objective analysis by qualified individuals indicates serious erosional problems, then reduction of erosional impacts should be a primary concern. In some areas, this may dictate the method of land use for the area or may in fact eliminate a land use because reduction of erosional impacts is economically impossible at the time.

6. ROUTE RECONNAISSANCE AND LOCATION

Armed with the guides and constraints developed during the land use planning process, the next step is to determine the specific road location. Alternative routes should be carefully reviewed in the office and at the site, utilizing all available background information (soil surveys, etc.) and technical expertise. Some important guidelines to help reduce erosional impacts during road location are:

1) Avoid high erosion hazard sites, particularly in areas where mass erosion is a problem. In such areas, slight location changes can often eliminate a major erosion problem.

2) Minimize the area of road disturbance by taking advantage of terrain features such as natural benches, ridgetops, and lower gradient slopes.

3) If necessary, include short road segments with steeper gradients (consistent with traffic needs) to avoid problem areas or to take advantage of terrain features.

4) Avoid midslope locations on long, steep, unstable slopes, especially where bedrock is highly weathered or soils are plastic.

5) Locate roads on well-drained soils and rock formations that tend to dip into the slope; avoid slide prone areas characterized by seeps, clay beds, concave slopes, hummocky topography, and rock layers that tend to dip parallel to the slope.

6) For timber harvest roads, take advantage of natural log landing areas (flatter, better drained, open areas) to reduce soil disturbance associated with log landings and temporary work roads.

7) Avoid undercutting unstable, moisture laden toe slopes when locating roads in or near valley bottoms.

8) Vary road grades where possible to reduce concentrated flow in road drainage ditches and culverts and to reduce erosion on the road surface.

9) Select drainage crossings to minimize channel disturbance during construction and to minimize approach cuts and fills.

10) Locate roads far enough above streams to provide an adequate buffer area or be prepared to catch sediment moving downslope below the road. A number of guides have been developed for establishing width of buffer areas based upon hillslope gradient, parent material, cross drain spacing, etc. (e.g., 23, 27). The guide developed by Packer (23) is presented as Table 2.

7. ROAD DESIGN

Road design involves translating field location survey and other data into specific plans to guide construction. Design criteria must be flexible to allow for modifications to minimize erosion hazards under varying site conditions. This is the stage of development where various measures to control erosion and reduce off-site erosional impacts are incorporated into the road design.

Revegetation and associated practices are important considerations during the design process. In addition, future maintenance needs are an important consideration to assure stability and economical use of the completed road. If regular maintenance cannot be assured, this must be accounted for in the design so that undue erosion will not occur.

A number of possible erosion control practices can be included in the road design process:

1) Use as narrow a road as possible commensurate with traffic speed and safety requirements and erosion hazards. In certain situations it may be necessary to reduce speeds and provide for alternative safety measures (e.g., restricted road use) to assure a narrow road in high erosion hazard areas.

2) Attempt to balance the volume of cut and fill material to minimize excavation. Use proper layer placement and compaction techniques wherever possible on fills to assure stability against mass failure.

3) Use full bench construction (no fill slope) where stable fill construction is impossible. Haul excavated material to safe disposal areas. Include waste areas in soil stabilization planning for the road.

4) Where full bench construction is impractical, properly designed retaining walls provide an effective but costly alternative to hold fill material.

5) Use the steepest slopes possible on cut and fill slopes commensurate with the strength of the soil and bedrock material as established by an engineering geologist or other specialist in soil mechanics. Benching cut slopes in areas of weak or erodible bedrock (e.g., weathered granites) into a series of properly drained terraces provides opportunity for vegetation establishment and may even require less excavation.

6) Properly designed road surfacing is often required to prevent excessive roadway erosion and maintain a usable road. The surface required depends on many factors such as the type and volume of traffic, strength of subgrade, service life, and materials available. Often, locally available gravels or crushed rock will serve the purpose. It may be desirable to surface both the road tread and the ditch in one operation.

Table 2 - Protective-strip widths required below the shoulders 1/ of 5-year old 2/ logging roads built on soil derived from basalt, 3/ having 9 m cross-drain spacing, 4/ zero initial obstruction distance, 5/ and 100% fill slope cover density. 6/

Obstruction spacing	Depressions or mounds	Logs	Rocks	Trees and stumps	Slash and brush	Herbaceous vegetation
	Protective-strip widths by type of obstruction					
	Meters					
0.3	10.6	11.2	11.6	12.1	12.5	13.1
.6	11.3	12.2	13.1	14.0	14.9	15.9
.9	11.9	13.1	14.3	15.9	17.4	18.6
1.2	12.2	14.0	15.9	17.7	19.5	21.3
1.5	12.5	14.6	17.0	19.2	21.6	23.8
1.8		15.2	18.0	20.7	23.5	26.2
2.1		15.9	18.9	22.2	25.6	28.7
2.4		16.2	19.8	23.5	27.1	30.8
2.7		16.5	20.4	24.7	29.0	32.9
3.0				25.9	30.5	35.1
3.4				27.8	31.7	36.9
3.7						38.7

1/ For protective-strip widths from centerlines of proposed roads, increase widths by one-half the proposed road width.

2/ If storage capacity of obstructions is to be renewed when roads are 3 years old, reduce protective-strip widths 7 m.

3/ If soil is derived from andesite, increase protective-strip widths 30 cm; if from glacial silt, increase 1 m; if from hard sediments, increase 2.4 m; if from granite, increase 2.5 m; and if from loess, increase 7 m.

4/ For each 3 m increase in cross-drain spacing beyond 9 m, increase protective-strip widths 30 cm.

5/ For each 1.5 m increase in distance to the initial obstruction beyond zero (or the road shoulder), increase protective-strip widths 1.2 m.

6/ For each 10% decrease in fill slope cover below a density of 100%, increase protective-strip widths 30 cm.

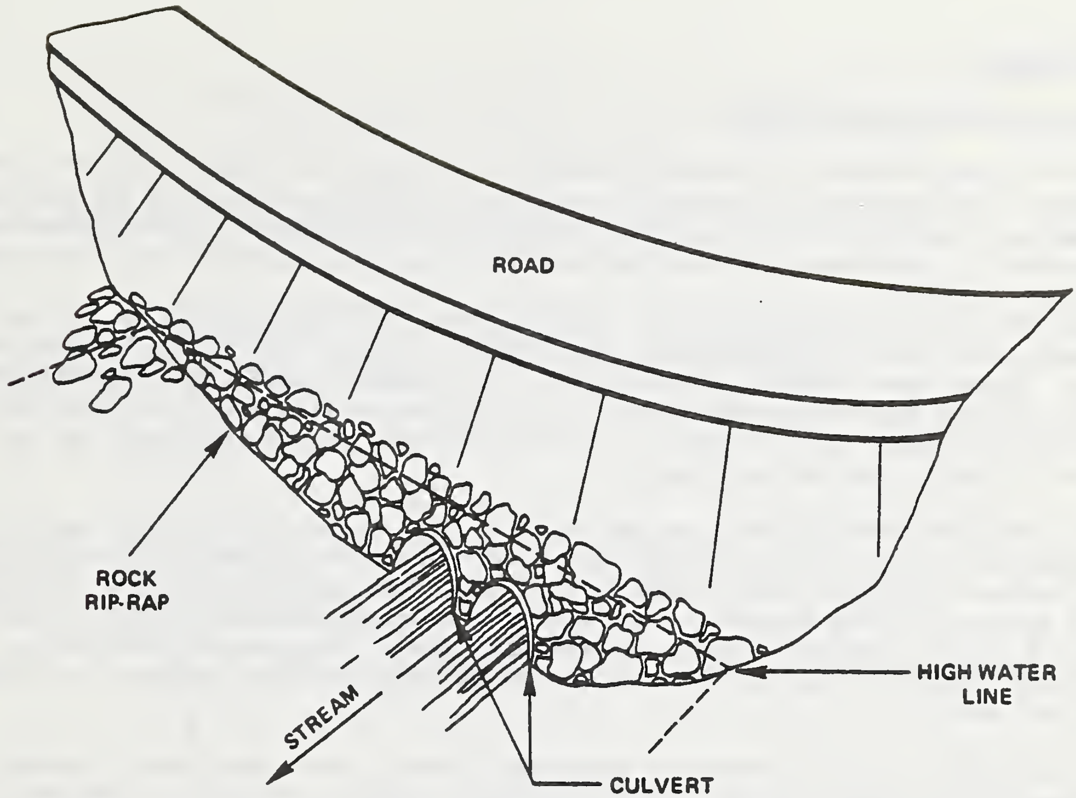

Figure 3. Rock rip-rap protection for embankment at a culvert installation.

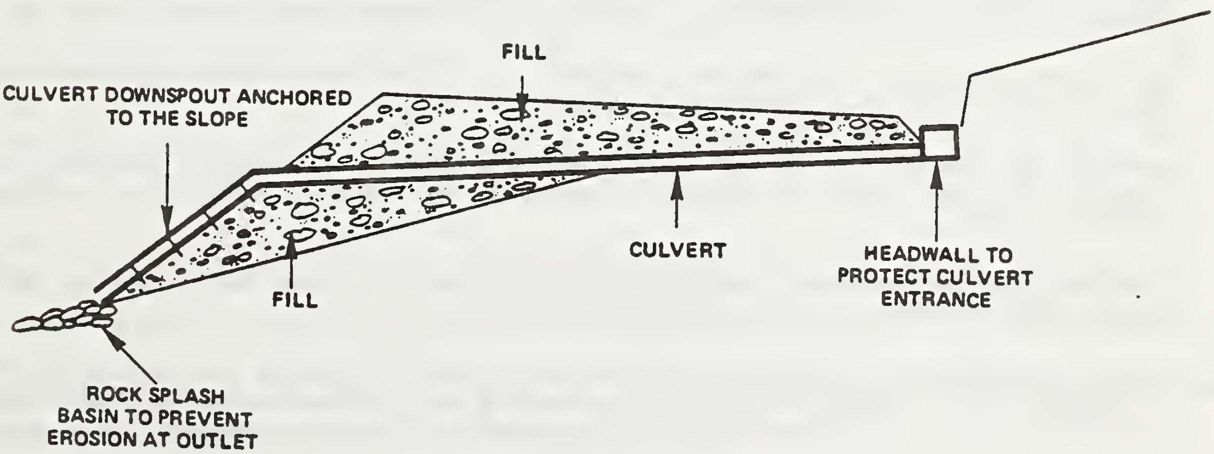

Figure 4. Culvert installation illustrating the use of a headwall, downspout, and a splash basin at the downstream end.

7.1 Road drainage

7.1.1 Crossing natural drainageways

There are three methods for crossing natural drainageways: fords, culverts, and bridges. Factors influencing the appropriate crossing include construction and maintenance cost, equipment and supplies available, debris potential, stream size, contemplated road use and life, foundation conditions, and vertical position of the road relative to the stream.

1) Fords are attractive alternatives for crossing small streams, particularly in areas where large amounts of rock, sediment, and organic debris tend to plug bridges or culverts. Fords cause minimal disturbance to the stream channel, are inexpensive, and avoid many of the problems associated with bridge and culvert installation. Fords require stable channel bottoms able to support vehicles or channels that can be protected by gabions or paving (Fig. 2).

2) Culverts (metal or wood) or bridges are required for channels where fords are impractical. Availability of construction equipment and materials, size of stream, potential for debris, terrain steepness, and reliability of the calculation for determining culvert capacity are some of the points to consider when deciding whether to use a culvert or a bridge at a given location. Other factors being equal, bridges are preferable, particularly in areas with debris or excessive sediment problems because the chances of failure are less.

   Structures should be large enough to carry the flows to which they are subjected within acceptable limits of risk. Costs increase rapidly with size so adequate local hydrological studies are needed. It is important to base the size requirement on the anticipated risk of failure rather than on the return interval of the flow alone (Table 3). The percent chance of failure established for a given structure will depend upon the anticipated economic and environmental hazards.

3) Roads should climb away from channel crossings in both directions wherever practical so high water will not flow along the road surface. Surface sloped sections of the road if necessary to reduce sediment movement directly into the stream.

4) Where adequate maintenance can be assured, install open top culverts or dips in the road surface to direct road runoff on to filter strips rather than directly into the stream.

5) Use rip-rap (placed rock), masonry headwalls, or otherwise protect embankment and channel sides at drainage structures (Fig. 3).

6) Increase the capacity of bridges or culverts in areas where debris, sediment, or both types of problems exist. In extreme situations, this may mean doubling the capacity of the structure.

7) Frequently maintained trash racks (grates) over the inlet end may be useful where floating debris tends to plug culverts.

8) If at all possible, use bridges in areas where debris problems are severe and fords are impractical. Otherwise it may be necessary to construct rock - or gabion-protected fills with a dip to allow overflow in the event that culvert capacity is lost.

7.1.2 Drainage along the roadway

Drainage is needed along the roadway to remove water before it has a chance to concentrate and cause erosion. To help accomplish this, slope road surfaces laterally either outward or inward, depending on traffic needs and erosion hazards. Unfortunately, traffic can cause some rutting in the road surface that concentrates flow along the road in spite of the outsloping or insloping. Thus in many situations, additional cross-drainage measures are needed to interrupt this flow and divert it laterally before it has a chance to cause erosion problems.

Table 3 - Design flood recurrence intervals (years) needed to provide a given project life with a given chance of failure 1/

DESIGN LIFE (YEARS)	Percent chance of failure																		
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
5	98	48	32	23	18	15	13	11	9	8	7	6	6	5	5	4	4	3	3
10	*	96	63	46	36	29	24	21	18	15	14	12	11	9	8	7	6	5	4
15	*	*	93	68	53	43	36	30	26	23	20	17	15	13	12	10	9	8	6
20	*	*	*	91	71	57	47	40	34	30	26	23	20	18	15	13	12	10	8
25	*	*	*	*	38	71	59	50	43	37	32	28	25	23	19	17	14	12	9
30	*	*	*	*	*	85	71	60	51	44	39	34	30	26	23	20	17	14	11
35	*	*	*	*	*	99	82	70	60	51	45	39	34	30	26	23	19	16	13
40	*	*	*	*	*	*	94	79	68	59	51	45	39	34	30	26	22	18	14
45	*	*	*	*	*	*	*	89	76	66	57	50	44	38	33	29	25	21	16
50	*	*	*	*	*	*	*	99	85	73	64	56	49	43	37	32	27	23	18
55	*	*	*	*	*	*	*	*	93	80	70	61	53	47	42	35	30	25	19
60	*	*	*	*	*	*	*	*	*	88	76	66	58	51	44	38	33	27	21
65	*	*	*	*	*	*	*	*	*	95	82	72	63	55	48	41	35	29	23
70	*	*	*	*	*	*	*	*	*	*	89	77	68	59	51	44	38	31	24
75	*	*	*	*	*	*	*	*	*	*	95	83	72	63	55	48	41	34	26
80	*	*	*	*	*	*	*	*	*	*	*	88	77	67	59	51	43	36	28
85	*	*	*	*	*	*	*	*	*	*	*	94	82	72	62	54	46	28	29
90	*	*	*	*	*	*	*	*	*	*	*	99	87	76	66	57	48	40	31
95	*	*	*	*	*	*	*	*	*	*	*	*	91	80	70	60	51	42	33
100	*	*	*	*	*	*	*	*	*	*	*	*	96	84	73	63	54	44	34

1/ Based on the formula $J = 1 - (1 - 1/T)^N$, where N = Design Life, T = Flood Recurrence Interval, J = Chance of Failure (reference 5).

* More than 99.

Example: If a culvert through a road is to last for 20 years with a 30% chance of failure, the culvert should be designed for the 57-year flood recurrence event.

Table 4 - Cross-drain spacings required to prevent rill or gully erosion deeper than 2.5 cm on unsurfaced logging roads built in the upper topographic position 1/ of north-facing slopes 2/ having a gradient of 80% 3/ (reference 23, table 2).

Road grade (%)	Material					
	Hard sediment	Basalt	Granite	Glacial silt	Andesite	Loess
	Cross-drain spacing, m					
2	51	47	42	41	32	29
4	46	42	38	37	27	24
6	44	40	35	34	25	22
8	42	38	33	32	23	20
10	39	35	29	29	20	17
12	36	32	27	27	17	15
14	33	29	24	23	14	11

1/ In middle topographic position, reduce spacings 5.5 m; in lower topographic position, reduce spacings 11 m.

2/ On south aspects, reduce spacings 4.6 m.

3/ For each 10% decrease in slope steepness below 80%, reduce spacings 1.5 m.

1) <u>Outsloping</u> (i.e., sloping toward the downhill side of the road) of from 3-5% is preferable to insloping because it eliminates the need to develop facilities to dispose of the water draining down the inside of the road. Outsloping can be unsafe in some situations because of particular traffic requirements or unusual site conditions such as clayey road surfaces that are very slippery when wet. In addition, outsloping should only be used where runoff will flow off the road onto stable surfaces. Normally, this precludes the use of outsloping on fill portions of the road unless fill slopes are small and low in erodibility or are well protected by mulches, vegetation, or both.

2) <u>Insloping</u> (i.e., sloping toward the uphill side) of the road surface is preferred to outsloping in areas of unstable fills, except in the case of a contour road where there is no chance for lateral flow along the road. Water draining from the road is carried along the inside of the road either on the road surface itself or more commonly in a ditch. Culverts are installed periodically to carry the water under the road. Some points to consider when designing an insloped road are:

   a) Avoid using ditches or keep ditches to a minimum width and increase the number of cross drains to reduce the total area disturbed by construction.

   b) Plan ditch gradients steep enough (generally greater than 2%) to prevent sediment deposition.

   c) Install culverts frequently enough to avoid accumulations of water that will cause excessive erosion of the road ditch and the area below the culvert outlet. Surface the ditch in areas of erodible material (e.g., weathered granitics).

   d) Use a culvert size of at least 40 to 50 cm, depending on expected debris problems.

   e) Install culverts at the gradient of the original fill slope if possible: otherwise provide anchored downspouts to carry the water safely across the fill slope. Skew culverts 20° to 30° toward the inflow to provide better inlet efficiency and flow characteristics. Provide rock or other splash basins at the downstream end of culverts to reduce the erosion energy of the emerging water (Fig. 4).

   f) Protect the upstream end of culverts from plugging with sediment by using sediment catch basins, drop inlets, changes in road grades, headwalls, and recessed cut slopes.

   g) Install the culvert deep enough to assure that it will not be crushed by traffic loads. This requires a depth of about 1.2 m for metal culverts subjected to loads from large, loaded logging trucks.

3) In some areas, alternating inslope and outslope sections can be built into the road, especially if road grades are "rolled" (provide alternating adverse and favorable grades). In such instances, install dips or cross drains on the surface of the road to control erosion of the roadway.

4) It is usually necessary to construct cross drains in the road surface on either insloped or outsloped roads to help prevent erosion caused by water concentrations in ruts. Various types of cross drains are used, including open-top culverts and intercepting dips. Some points to consider when installing cross drains are:

   a) Spacing requirements - spacing depends on a number of factors such as road grade, and type of material. Guides for spacing are presented in Table 4.

   b) Open-top culverts are usually constructed of wood (Fig. 5). They should be installed at a 30° angle downslope to promote self cleaning and make crossing easier (Fig. 6). Culverts of this type <u>must</u> be properly maintained to prevent plugging and damage by traffic.

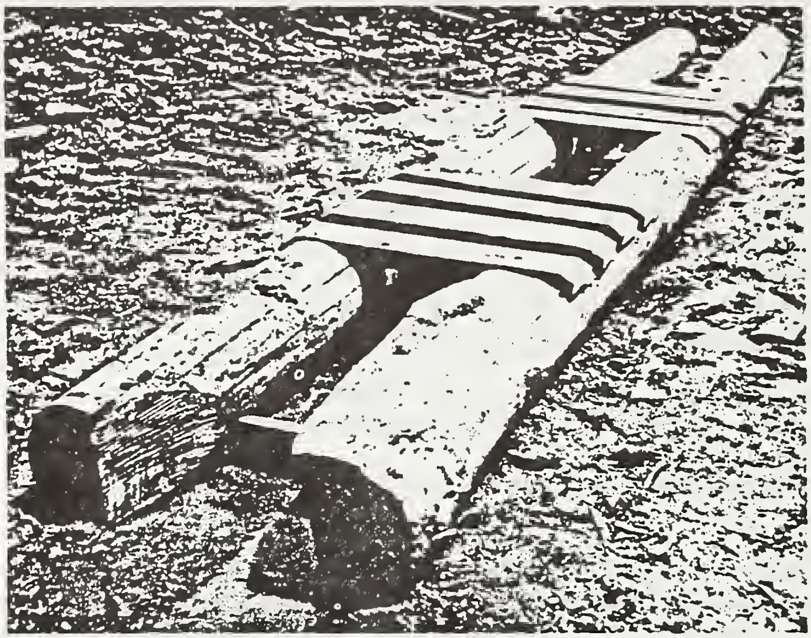

Figure 5. An open-top culvert constructed of wood. Spreaders on the bottom of the logs maintain culvert shape and the 5-cm spaces between the boards prevent water from running down wheel tracks and across the culvert.

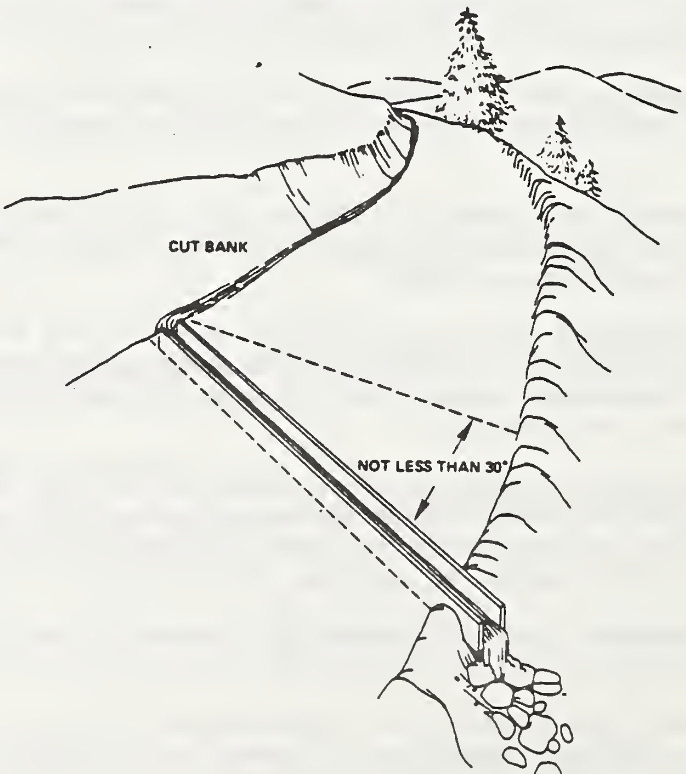

Figure 6. Installation of an open-top culvert. Culverts should be slanted at least 30° downslope to help prevent plugging.

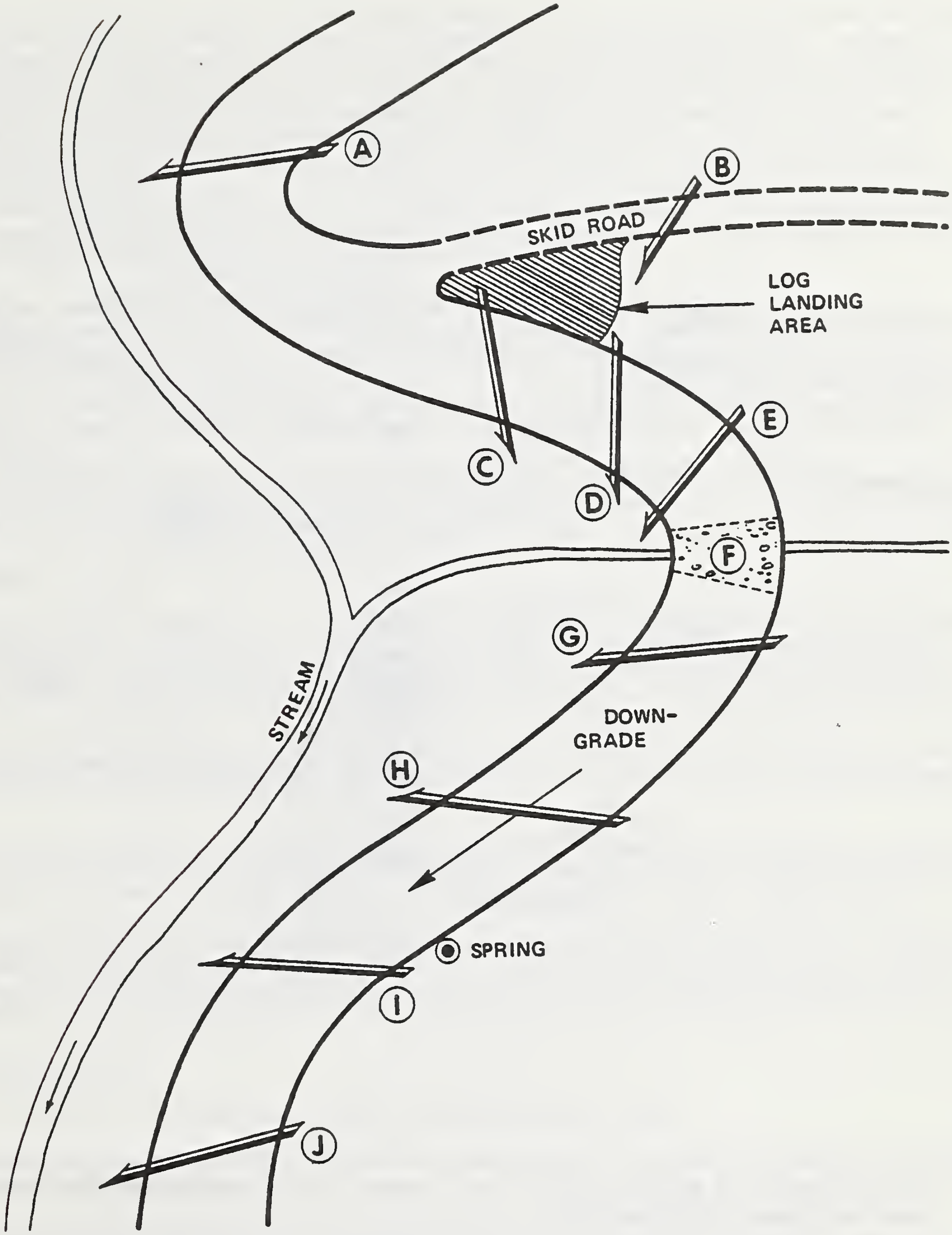

Figure 9. Guides for locating cross drains. Several locations require cross drains independent of spacing guides. A and J, divert water from ridge; A, B and C, cross drain above and below junction; C and D, locate drains below log landing areas; D and H, drains located with regular spacing; E, drain above incurve to prevent bank cutting and keep road surface water from entering draw; F, ford or culvert in draw; G, drain below incurve to prevent water from coursing down road; I, drain below seeps and springs.

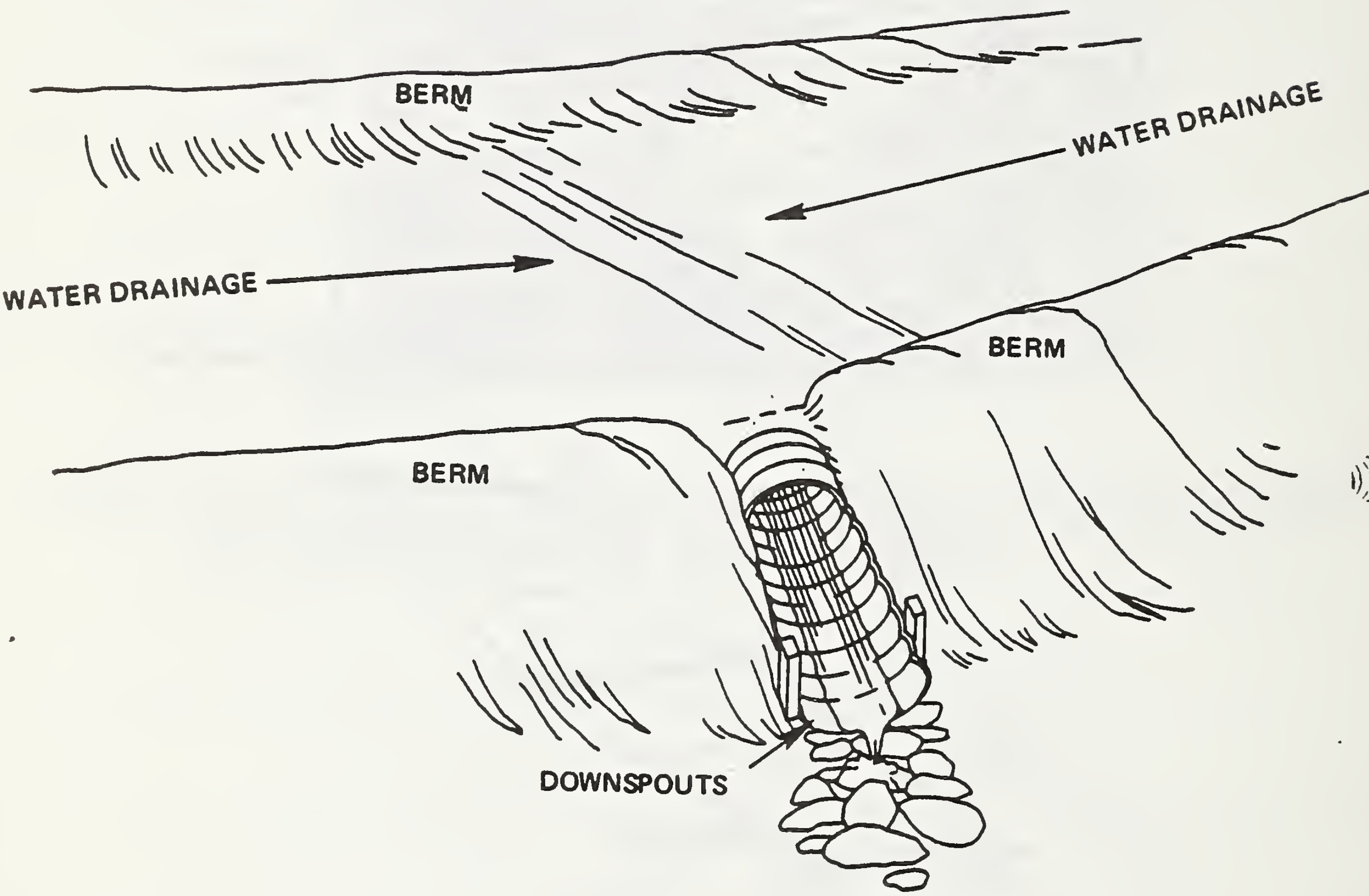

Figure 10. Construction of a downspout in a berm. Excess water accumulations on a berm must be drained by a downspout.

3) It is desirable to conduct seeding operations before mulching to attain maximum benefit from the mulch. However, this is not possible in some locations (e.g., areas with pronounced dry seasons) because the time of seeding or transplanting is critical. To illustrate, many locations on the west coast of the United States are influenced by a distinct Mediterranean climate causing a prolonged drought period in the summer. Seeding and planting operations during the drought period are usually failures; operations must take place in the fall to be successful. Transplanting through a previously applied mulch is often successful in these situations. Sometimes wattling (installing low barriers of soils and brush along the contour up and down the slope) is a successful substitute for mulching. Seeding, planting, or both, between the wattles can then be carried out at the proper time.

4) Species selection must be designed to meet local needs. Grasses have been most commonly used; however, forbs, shrubs, and trees alone or in combinations should be considered. Legumes have particular benefits as nitrogen fixers as do some other plants. Deep-rooted plants including both trees and shrubs can help increase mass stability as well as reduce surface erosion. Rapid-growing, short-lived species (e.g., some of the ryes and oats) are often desirable for nurse crops for slower growing vegetation.

5) Fertilization should accompany most revegetation operations. Proper types and amounts of fertilizer should be based upon soil analyses or experience in the area. Additional amounts may be required if organic mulches are used.

8.2 Mulches

In some areas, vegetation response is rapid enough to provide slope protection during the initial high erosion period. However, it is usually necessary to supplement the protection during the interim with mulches. Mulching provides additional benefits by reducing surface soil temperatures, water losses from the soil, and soil crust formation.

1) Many kinds of materials ranging from logging slash to peanut shells have been used for mulching. Type of material is not as important as the need to use sufficient amounts in close contact with the soil.

2) On steeper areas it is often necessary to anchor the mulch into the soil by covering it with netting material that is pinned in place, spraying adhesive chemicals (e.g., liquid asphalt, various polymers) onto the mulch, or rolling it with a spike roller.

3) Machines have been developed that combine mulching material (straw or wood fibre are commonly used) with water, an adhesive, or both, and spray the mixture onto the slope. Usually, seed and sometimes fertilizers are added to the mixture to provide multi-benefits in one operation.

8.3 Other practices

Other types of stabilization practices have also been used:

1) Recent development of polymers permits stabilization of disturbed areas by spraying the material on the surface.

2) Sometimes revegetation practices increase infiltration of water into the surface sufficiently to increase mass erosion hazards to the point of failure (11). In these cases, an impermeable material (e.g., asphalt, certain polymers, or even plastic sheeting) may be required to stabilize surfaces.

9. CONSTRUCTION

The construction phase is the moment of truth for a road development. The best planning and design is useless unless it is incorporated into the finished product. Competent planning and supervision of the construction phase is probably the single most important factor leading to success. This requires a thorough knowledge of construction methods, equipment, materials, and testing coupled with a sense of diplomacy to communicate with the individuals doing the work. Such a background will not only enable the construction supervisor to develop the road as planned but will also allow him to effectively deal with the inevitable design changes required during construction because of unforeseen circumstances (especially in earthwork and drainage installations).

Some important erosion control practices to consider during construction include:

1) Keep slope stabilization work as current as possible with road construction.

2) A thorough job of clearing and grubbing is required to insure proper construction of fills. Overcasting onto brush and timber or incorporating brush and timber into the fill material can lead to serious surface and mass erosion problems. In addition, provide a good base for fills and assure proper compaction as fills are constructed.

3) Where possible, the cleared vegetation should be spread evenly over the soil surface beneath the toe of the road fill. The vegetation material should be cut up or somehow crushed into the surface to assure close contact with the soil. This practice should enhance the buffering qualities of the slope beneath the road (see Table 2).

4) When installing culverts, avoid channel changes and place culverts so they conform to the natural stream channel as closely as possible. Remove as much debris from the channel above the culvert as possible. Carefully compact the fill material around all culverts to prevent seepage and ultimate culvert failure.

5) Keep stream disturbance to an absolute minimum and avoid it altogether during high flow periods.

6) Vagaries in weather conditions are an important factor leading to erosion during construction. In areas where the climate permits, plan jobs for completion during dry periods. Elsewhere, limit the work area to small sections than can be completed before proceeding further. This exposes a minimum of disturbed area to erosion forces in the event the weather changes. Light rains usually have limited erosional impacts. However, if obvious impacts occur during larger storms, be prepared to cease operations after installing emergency drainage as needed. It is advisable to install all designed drainage from the downstream end of the job to the upstream end in areas of unpredictable weather.

10. ROAD MAINTENANCE

Diligent maintenance is an absolute necessity to assure effective erosion control throughout the life of a road. Following construction, inevitable deficiencies in design and construction practices require modification or repair. Throughout the life of the road, traffic use and natural deterioration continue to make diligent maintenance a necessity.

Recommended maintenance practices are:

1) A maintenance record should be developed for each road consisting of the actual construction plans for the road and a tally of the kind and cost of maintenance operations required over time. The record will assist in training new personnel and provide a solid background of data to prevent extension of mistakes to roads in other areas.

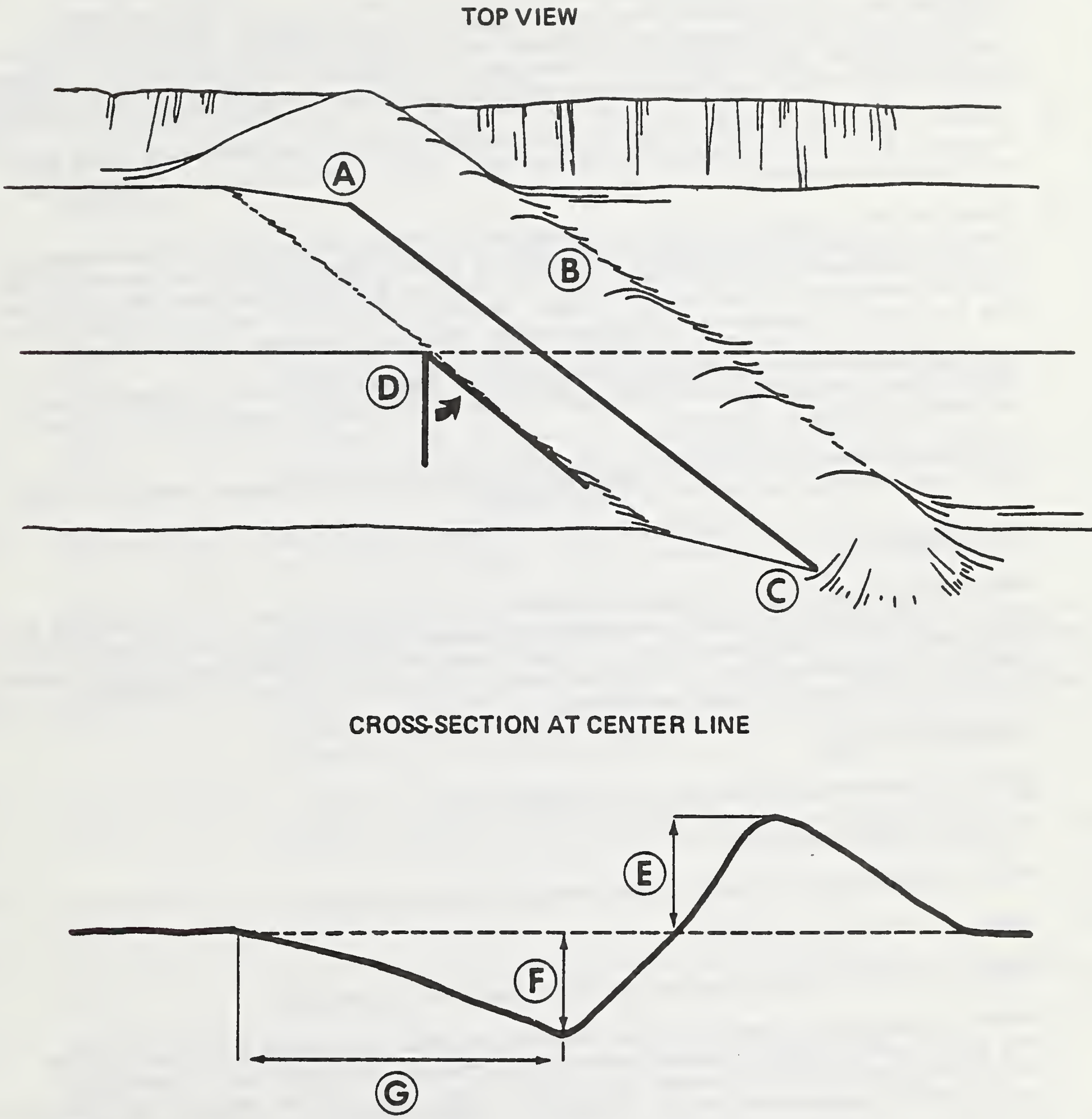

Figure 11. Cross ditch construction for forest roads with limited or no traffic. Specifications are average and may be adjusted to gradient and other conditions. A, bank tie-in point cut 15 to 30 cm into roadbed; B, cross drain berm height 30 to 60 cm above road bed; C, drain outlet cut 20 to 40 cm into road; D, angle drain 30° to 40° downgrade with road centerline; E, height up to 60 cm, F, depth to 45 cm; G, 90 to 120 cm.

2) Culverts, cross drains, and dips should be cleaned regularly to assure proper functioning, especially before winter or expected rainy seasons. Debris should be removed from live drainages for a distance of 30 m upstream from the inlet. Cross drains and dips are often damaged during high use periods or sometimes even removed for more efficient traffic flow; they should be replaced before rainy seasons or snowfall.

3) Ditches should be cleared of debris and sediment accumulations with care being taken to avoid disturbing stabilized ditch bottoms. Avoid undercutting the roadcut when removing slide debris.

4) Grade the road surface as often as necessary to retain the original surface drainage (either insloped or outsloped). Take care to avoid side-casting graded material over the fill slope. Carefully monitor surface drainage during wet periods and close the road if necessary to avoid undue damage. Restore surfacing on the road tread and in the road ditch if necessary following damage caused by operation in wet periods.

5) Haul all excess material removed by maintenance operations to safe disposal areas. Apply stabilization measures on disposal sites if necessary to assure that erosion and sedimentation do not occur.

6) During large storms or excessive snowmelt it is beneficial to patrol roads to assure that road drainage facilities are functioning.

11. ROAD CLOSURE

Many roads, especially work roads associated with timber harvesting, are designed for use only for a short time. These roads should be closed along with any other roads that are needed only for intermittent travel to minimize maintenance expense and erosion hazards. Two possible situations exist: (a) the road should be closed, but use is anticipated in the future; and (b) permanent closure is desired.

11.1 Temporary closure

Steps recommended for temporary road closure are:

1) Block the road to vehicles.

2) Remove all temporary culverts including brush and wood types.

3) Remove all temporary bridges.

4) Remove all other culverts and bridges that cannot be maintained.

5) Except on large fill slopes, outslope the road surface and remove all berms, taking care not to spill graded material over the fill slope. The best way to accomplish this is to grade material toward the cut bank. Outslope only enough to divert water over the bank (approximately 2 to 3% plus the slope gradient of the road in percent).

6) When removing culverts and bridges, be sure all fill material is removed from below the high water line of the stream. All material that is removed should be placed in a safe disposal area. The remaining fill material should be left at a stable angle.

7) Cross ditch the road tread in accordance with the cross ditch design shown in Figure 11, and the cross-drain spacing guides in Table 4 and Figure 9.

8) Revegetate the road surface and areas disturbed by road closure operations along with any other areas of exposed soil. Use all revegetation procedures necessary (including mulching) to stabilize the site.

11.2 Permanent closure

Similar procedures are used for permanent road closure except that all bridges and culverts are removed. In addition, it is also desirable to break up road surface compaction to reduce runoff and provide a better site for revegetation. Ripping with a hydraulic ripper is an effective way to accomplish this. Fill material should be removed from any area where mass failure is possible in the future. Place material in a safe disposal area and use erosion control methods at the disposal area.

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GUIDES FOR CONTROLLING SEDIMENT FROM SECONDARY LOGGING ROADS

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CONTENTS

PREFACE

For a long time we have known that the manner in which secondary forest roads are built and where they are located in watersheds have important effects on the quality of water in streams. Experience and research have taught us that the relations between roads and sedimentation of streams are not simple. Such factors as geology, soils, topography, vegetation, and climate influence these relations tremendously.

We know the general nature of forest road effects on sedimentation; for instance, that roads built too close to stream channels can ruin the quality of water in these streams. Numerous practical measures, including the use of berms, surfacing, surface drainage structures, and outsloping, have been employed to reduce erosion on roads and prevent sediment from reaching streams. Despite use of such preventive measures, erosion of road surfaces and fill slopes and movement of sediment from roads into streams continue on many of our timber sale areas. These conditions indicate that we do not yet fully understand what kinds of roads to build nor where to locate them in watersheds in order to prevent sedimentation.

Prospects for increased timber harvesting and other uses of forest land emphasize the need to understand how to locate and build the roads needed to serve these uses without causing undue damage to soil and water resources.

The guides in this handbook are largely the result of recent research in the Northern Region and also are partly the result of experience. They provide you with a basis for understanding how and where roads may be built safely under varying conditions of soil, topography, and vegetative cover. We urge you to become familiar with these guides and apply them to the fullest extent possible in planning and constructing secondary forest roads.

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INTRODUCTION

Water produced on National Forest lands is used for many purposes and is reused many times before it reaches the ocean. Clear, pure water is necessary for household and agricultural uses and for many processes in manufacturing. Important and valuable commercial and sport fisheries depend upon clean water.

Sediment in streams scours some channel sections and fills others, causing flood damage to cities, farms, transportation systems, and communication facilities. It destroys fish foods and spawning beds, damages power-generating turbines, and fills reservoirs, canals, and irrigation ditches. Sediment must be prevented from entering streams or stream channels.

Measurements and observations indicate that as much as 90 percent of the sediment produced by erosion on timber sale areas is from roads. Research and experience show that damage to soil and water can be largely prevented by conscientious application of specific guides for design, location, construction, and maintenance of forest roads.

This handbook contains such guides to help you in locating and designing secondary logging roads and installing water control structures in a way that will reduce erosion and prevent sedimentation of streams.

Application of this guide is most valuable in locating and designing the logging road system during the planning for a new timber sale. Another valuable application of the guide is in the development on existing secondary roads of measures for controlling erosion and preventing sediment.

Recent research by the Intermountain Forest and Range Experiment Station indicates that the surfaces of secondary logging roads deteriorate rapidly when rills are allowed to erode deeper than about 1 inch (fig. 1).

The distances that water flows down road surfaces before eroding rills to 1-inch depth determine what spacings are required between cross drains on road surfaces to prevent such erosion. The distances that sediment moves downslope from outlets of cross drains determine the widths of protective strips needed below roads to control sediment (fig. 2).

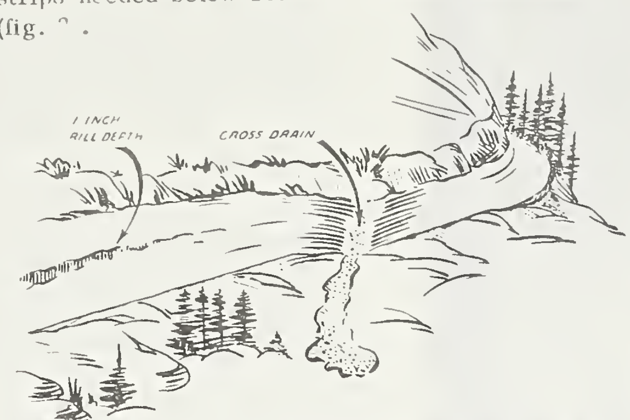

Figure 1.--Rill erosion on a road surface below a cross drain.

Figure 2.--Sediment movement downslope from a road cross drain.

Most factors that affect erosion of road surfaces and movement of sediment can be controlled. Consequently the severity of road surface erosion and the distance that sediment moves downslope also can be controlled by applying certain preventive measures during and after roadbuilding and logging.

FIVE FACTORS AFFECT EROSION OF SURFACES OF FOREST ROADS

1. Size of soil particles

The larger the proportion of coarse soil material (larger than about 0.1 inch in diameter) on the road surface, the less likely it is to be eroded by snowmelt runoff or heavy rains. Hence, cross drains may be installed farther apart on a surface that contains mainly coarse particles than on one composed chiefly of fine particles.

The more important forest soils in the Northern Region have been classified into six groups based upon the proportion of coarse particles and water-stable aggregates larger than about 0.1 inch in diameter on road surfaces (table 1). The parent materials from which the major kinds of soil in each group were derived are also listed in table 1 as a guide to selection of the proper soil group for your later use in determining spacings of cross drains and widths of protective strips.

Table 1. Forest soil groups in order of (1) decreasing coarseness and increasing detachability of soil on road surfaces and (2) major parent materials in each group

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
decreasing coarseness and increasing detachability of road surface soil					
hard sediments shale (hard) slate argillite rhyolite rhyolite porphyry limestone (hard)	basalt basalt porphyry quartzite conglomerate gravel	granite sandstone gneiss schist sand	glacial silt shale (soft)	andesite andesite porphyry limestone (soft)	loess

2. Steepness of road grade

Since rill erosion does not occur on truly level roads, these roads need no cross drains. But as road grades get steeper, erosion increases, and cross drains must be installed closer together. Designing roads with gentle grades reduces the number of cross drains needed.

3. Topographic position

The nearer a road is to the top of a sidehill, the less the surface will wash during snowmelt runoff or a heavy rain. But if the road is near the bottom of a sidehill, cross drains will have to be spaced close together.

4. Direction of exposure

Roads on north-facing slopes are likely to erode less than those on south-facing slopes. They generally require fewer cross drains.

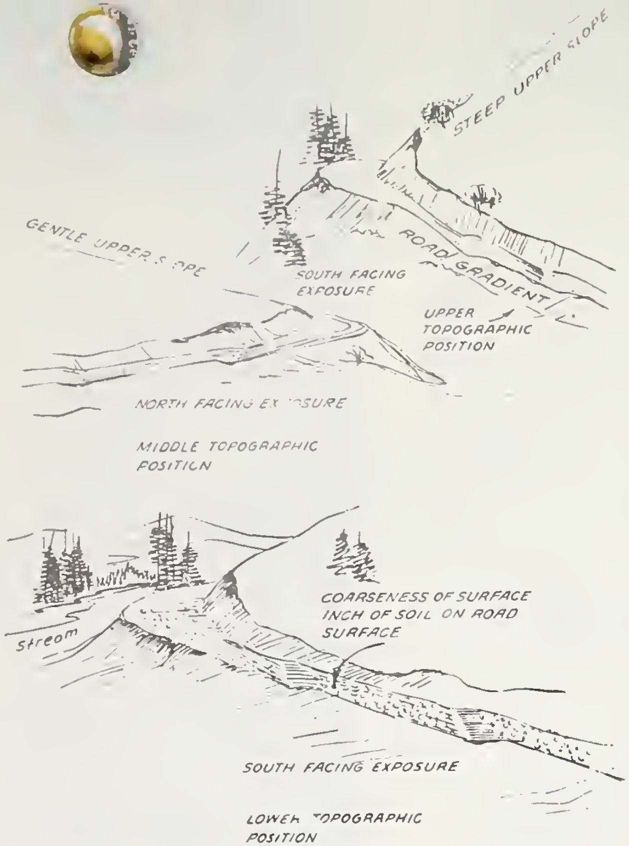

Figure 3.--Factors affecting erosion of road surface.

5. S___ess of sidehill

The steeper the sidehill across which a road is built, the wider can be the space between cross drains.

SEVEN FACTORS AFFECT MOVEMENT OF SEDIMENT BELOW SHOULDERS OF FOREST ROADS

1. Spacing of cross drains

Sediment from cross drains flows farther downslope from road shoulders when cross drains are farther apart.

2. Spacing of obstructions

Sediment flows farther down road fills and slopes below fills when obstructions that touch the ground (logs, rocks, brush, etc.) are spaced farther apart. The more closely obstructions are spaced, the narrower may be the widths of protective strips between roads and streams.

3. Kinds of obstructions

Different kinds of obstructions on fills and on slopes below fills reduce downward flow of sediment by different amounts. Obstructions that retard sediment flow, in order of decreasing effectiveness, are:

Figure 4.--Factors that affect distance sediment moves downslope.

Depressions made by pushed-over or wind-thrown trees, or a wavy ground surface

b. Logs thicker than 4 inches

c. Rocks more than 4 inches wide at ground surface

d. Trees and stumps

e. Slash and brush

f. Grass, weeds, and shrubs.

This comparative list is important because it shows you can reduce the width of protective strips below roads by installing such effective obstructions as logs and rocks and spacing them reasonably close.

4. <u>Distance to first obstruction</u>

The closer to the outlet of a cross drain you install an obstruction, the shorter the distance that sediment will move. If the first obstruction is located at the outlet of a cross drain, the protective strip can be comparatively narrow.

5. <u>Density of cover on fill slope</u>

Sediment moves farther downslope as the density of ground cover decreases. Therefore,

protective cover should be established as soon as possible on road fill slopes.

6. Size of soil particles

The size of material in the surface inch of mineral soil on slopes adjacent to logging roads is important. The smaller the size of soil particles, the farther the sediment will move.

In each of the six soil groups (table 1), the proportion of coarse soil particles and aggregates (larger than 0.1 inch in diameter) on natural slopes adjacent to roads is smaller than it is on road surfaces. This is because rainfall runoff and snowmelt have washed more of the finer soil off bare road surfaces. The order of decreasing coarseness of soil in these groups when it is on slopes adjacent to roads is also the order of increasing distance that sediment flows down slopes:

Groups 2 and 5	coarse
Group 4	moderately coarse
Groups 1 and 3	moderately fine
Group 6	fine

The difference between this order of decreasing coarseness and the order these soil groups show on road surfaces is probably due to differences in such physical characteristics of particles and aggregates as their shape and angularity, which affect the ease of their movement from road surfaces.

7. Age of roads

As the age of roads increases from 1 to 3 years, the distance that sediment moves downslope from them increases slightly. As age increases to 4 and 5 years, sediment moves much farther downslope. The sudden increase in distance of sediment movement in the fourth and fifth years is due to the filling of storage capacity for sediment above the obstructions (fig. 5). This relation indicates that where the width of a protective strip is critical for preventing sediment damage to a stream, the strip can be narrower if water from cross drains is diverted toward other existing obstructions or if new obstructions are installed when the road is 3 years old.

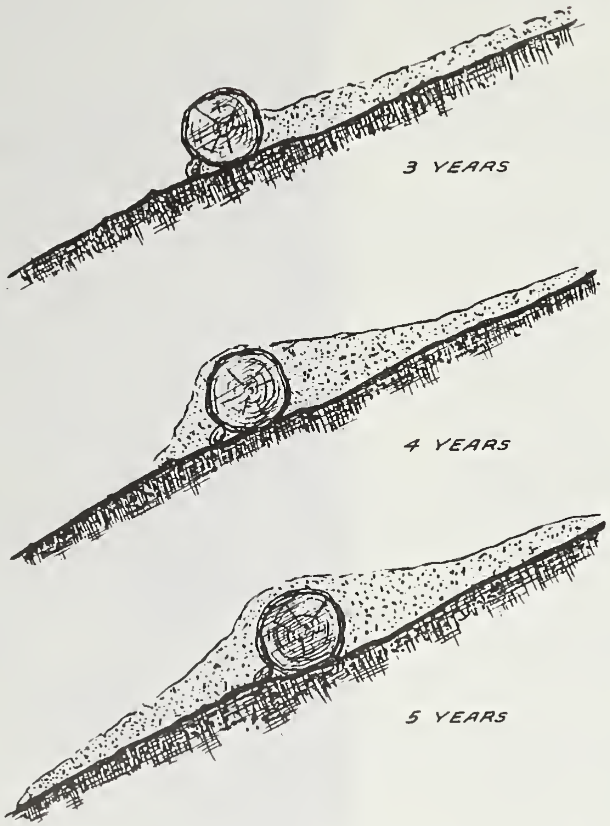

Figure 5.--Influence of age of a road on the effectiveness of obstructions for trapping sediment.

GUIDES FOR SPACING CROSS DRAINS AND DETERMINING WIDTHS OF PROTECTIVE STRIPS

The next two tables can help you determine spacings between cross drains and widths of protective strips needed for controlling sediment, provided you have some knowledge of watershed factors and of characteristics of road design.

GUIDE FOR SPACING CROSS DRAINS

Cross-drain spacings necessary to stop 83 percent of rills on road surfaces before they erode deeper than 1 inch vary according to soil type and steepness of road grade (table 2). Instructions below table 2 enable you to adjust spacing of cross drains according to differences in exposure, topographic position, and steepness of the slope above the road.

If roads are to be built in watersheds where high quality of water must be guaranteed, assurance that rills and gullies deeper than 1 inch do not develop may be increased from 83 percent to about 97 percent by reducing the spacings shown in table 2 by 45 feet. Wherever the combination of soil and topographic features requires spacing of cross drains less than about 30 feet, no logging roads should be built unless they will be surfaced with gravel or crushed rock.

Table 2. Cross-drain spacings required to prevent rill or gully erosion deeper than 1 inch on secondary logging roads

Road grade (percent)	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
	Soil group on which road is located or built — Cross-drain spacing (feet)					
2	167	154	137	135	105	95
4	152	139	122	120	90	80
6	144	131	114	112	82	72
8	137	124	107	105	75	65
10	128	115	98	96	66	57
12	119	106	89	87	57	48
14	108	95	78	76	46	37

Table is based on location of road in the upper one-third of north facing slopes having steepness of 80 percent.

INSTRUCTIONS:

To determine cross-drain spacings for other positions on slope, different exposures, and sidehill slope steepness less than 80 percent, apply the following instructions.

1. If road is located in the middle one-third of a slope, space 18 feet closer than shown in table 2; if it is in the bottom third of a slope, space 36 feet closer.

2. If road is located on an east or west exposure, space cross drains 8 feet closer than shown in table 2; if road is on a south slope, space 16 feet closer.

3. For each 10-percent decrease in steepness of the sidehill slope from a gradient of 80 percent, space cross drains 5 feet closer than shown in table 2.

GUIDE FOR DETERMINING WIDTHS OF PROTECTIVE STRIPS

Ideally a logging road should be located far enough from a stream or other site needing protection so that sediment from the road cannot reach it. To achieve this protection, road locators allow for a strip of ground between the edge of the fill slope and the site to be protected. Minimum widths needed to achieve this protection vary according to kinds of obstructions below roads, the spacing between these obstructions, relative stability of soils, distances between cross drains, distance from cross-drain outlet to first obstruction, density of cover on the fill slope, and the periodic renewal of capacity of obstructions for storing sediment.

Minimum widths necessary to stop 83 percent of sediment flows on sites where soils are relatively stable (those derived from parent materials listed in groups 2 and 5, table 1) are shown in table 3. These widths represent total width of protective strip below the road centerline. Instructions immediately following table 3 show the amounts by which these widths must be altered to allow for differences in soil type, spacing of cross-drains, distance to first obstruction, and density of cover on the fill slope.

Table 3.--Protective-strip widths[1] required from the centerlines of roads in order to prevent sediment from reaching sites needing protection

Obstruction spacing (feet)	Depressions or mounds	Logs	Rocks	Trees and stumps	Slash and brush	Herbaceous vegetation
	Width of protective strip (feet)					
1	53	55	56	58	59	61
2	55	58	61	64	67	70
3	57	61	65	70	75	79
4	58	64	70	76	82	88
5	59	66	74	81	89	96
6		68	77	86	95	104
7		70	80	91	102	112
8		71	83	95	107	119
9		72	85	99	113	126
10				103	118	133
11				106	122	139
12						145

[1] Figures in this table assume soils from groups 2 and 5, conditions of 30-foot spacing of cross drains, zero distance from cross-drain outlet to first obstruction, zero density of cover on fill slopes, and no plan to maintain capacity of obstructions for retarding and trapping sediment.

INSTRUCTIONS:

To determine protective-strip widths for soils in groups other than 2 and 5, for spacing of cross drains greater than 30 feet, for distance to first obstruction greater than zero, and for density of cover on the fill slope greater than zero, you should apply the following instructions (see example, pp. 24-25):

1. If soil is derived from group 4, increase the width of the protective strip shown in this table by 5 feet. If soil is from group 1 or 3, increase by 10 feet; if from group 6, increase by 24 feet.

2. For each 10-foot increase in spacing of cross drains beyond 30 feet (see table 2), increase width of protective strip 1 foot.

3. For each 5-foot increase in distance to first obstruction, increase width of protective strip 4 feet.

4. For each 10-percent increase in density of cover on fill slope above a density of zero, decrease width of protective strip 1 foot.

Where a logging road is proposed for construction close to a stream channel, assurance that sediment will not reach the stream can be increased to about 97 percent by increasing the protective-strip widths shown in table 3 by 30 feet.

SUPPLEMENTARY GUIDES FOR ESTIMATING WATERSHED FACTORS THAT CANNOT BE MEASURED DIRECTLY

Where logging roads are to be located, some of the watershed factors that affect the required widths of protective strips will be changed by subsequent roadbuilding and/or logging operations. The values that these factors will probably attain after road construction and/or logging will have to be estimated. The following guides have been developed to help you make these estimates.

Densities of cover on fill slopes.--The amounts of plant and litter cover on fill slopes cannot be measured when the roads are being located. Hence you must estimate the density of cover to be expected after the road is built. Research has shown that cover on fill slopes remains sparse for several years on most logging roads in the Northern Region. An estimate of zero density for fill slope cover therefore appears to be safe because it will insure prescribing of adequate widths of protective strips. If fill slopes are to be seeded and mulched in the same year they are constructed, cover densities greater than zero may be justified for use in instruction 4 with table 3.

Distances to first obstructions.--Normally, few major obstructions to sediment flow occur on fill slopes. Where these slopes are chiefly loose soil, distance to the nearest obstruction depends upon the gradients of the slopes above and below the road and upon width of the road. The longest distances to the first obstruction to be expected in 97 percent of cases are shown in table 4.

Spacing of obstructions.--The different kinds of treatments that slopes below roads may receive after centerlines have been located and staked may greatly alter the spacing of obstructions. If these slopes are to be logged, expected spacing of obstructions cannot be measured before the logging operation. Logging debris may be left intact or disposed of by any of several methods involving

piling and/or burning. The degree of piling and burning usually varies with the logging operator, climatic conditions, and other factors. Consequently, the largest average spacings encountered in about 97 percent of cases for each of the six frequent types of obstructions on the study sites were selected as safe obstruction spacings because they will seldom be exceeded. These spacings are:

Obstructions	Spacing (feet)
Depressions and mounds	5
Logs	9
Rocks	9
Trees and stumps	11
Slash and brush	11
Herbaceous vegetation	12

Table 4.--Longest distances[1] from road shoulder to first obstruction for roads 12, 14, and 16 feet wide, by steepness of upper and lower slopes

Lower slope steepness (percent)	Upper slope steepness (percent): 1-20			21-40			41-60			61-80		
	Road width (feet)											
	12	14	16	12	14	16	12	14	16	12	14	16
10	15	15	15	16	16	16	16	16	17	17	17	17
20	16	16	16	16	17	18	17	18	19	18	19	20
30	16	17	18	17	19	20	19	20	22	20	21	23
40	16	18	20	18	21	23	21	23	25	22	24	26
50	17	19	22	19	22	25	22	25	28	24	27	30
60	17	20	23	20	24	27	24	27	31	26	29	33
70	18	21	25	22	26	29	26	29	34	28	32	36
80	18	22	27	23	28	32	28	32	37	31	35	40

[1] To be expected in 97 percent of cases.

Kinds of obstructions.--The kinds of obstructions remaining on slopes below logging roads depend upon characteristics of surface relief, initial cover conditions, and the kinds of logging and postlogging cleanup treatments applied to the slopes. Gentle slopes (to about 25 percent), for instance, are generally characterized by undulating or wavy topography having depressions that trap considerable sediment. Steeper slopes have fewer undulations, and depressions on them have much less capacity for stopping and storing sediment.

On timbered slopes, trees are major obstructions to movement of sediment. When these slopes are logged, obstructions are chiefly the remaining logs, stumps, and slash. Broadcast burning of logging debris eliminates most of the slash and leaves only logs and stumps. Dozer piling and burning eliminates most of the slash and logs and leaves only stumps as major obstructions to sediment flow.

Table 5 is designed to help you by listing the kinds of obstructions that usually are present on lower slopes subjected to different logging and postlogging treatments.

Table 5.--Obstructions usually found on slopes below roads by type of cover, steepness of slope, clear cut logging treatment, and method of postlogging cleanup

Lower slope cover	Lower slope steepness	Treatment	Postlogging cleanup	Obstructions[1] on lower slopes[2]
	Percent			
Timbered-brushy	<25	none	none	D-T-B
	<25	logged	none	D-L-S-SL-B
	<25	logged	broadcast burned	D-L-S-H
	<25	logged	dozer piled-burned	D-S-B-H
	>25	none	none	T-B
	>25	logged	none	L-S-SL-B
	>25	logged	broadcast burned	L-S-H
	>25	logged	dozer piled-burned	S-B-H
Timbered-rocky	<25	none	none	D-R-T
	<25	logged	none	D-L-R-S-SL
	<25	logged	broadcast burned	D-L-R-S-H
	<25	logged	dozer piled-burned	D-R-S-H
	>25	none	none	R-T
	>25	logged	none	L-R-S-SL
	>25	logged	broadcast burned	L-R-S-H
	>25	logged	dozer piled-burned	R-S-H

Table 5. (Con.)

Lower slope cover	Lower slope steepness	Treatment	Postlogging cleanup	Obstructions on lower slopes
	Percent			
Timbered not brushy or rocky	<25	none	none	D-T
	<25	logged	none	D-L-S SL
	<25	logged	broadcast burned	D-L-S-H
	<25	logged	dozer piled-burned	D-S-H
	>25	none	none	T
	>25	logged	none	L-S-SL
	>25	logged	broadcast burned	L-S-H
	>25	logged	dozer piled-burned	S-H
Untimbered-brushy	<25	none	none	D-B-H
	>25	none	none	B-H
Untimbered-rocky	<25	none	none	D-R-H
	>25	none	none	R-H
Untimbered-herbaceous	<25	none	none	D-H
	>25	none	none	H

[1] D = depression; L = log; T = tree; S = stump; R = rock; SL = slash; B = brush; and H = herbaceous vegetation.

[2] In decreasing order of effectiveness for stopping sediment.

HOW TO APPLY THESE GUIDES FOR CONTROLLING EROSION AND SEDIMENT FLOW

The guides established in the previous section cannot be substituted for good judgment and experience in designing and locating logging roads. The guides are merely working tools to help you make some necessary decisions. It is assumed that anyone who uses these guides is already well acquainted with the many circumstances in road construction that may lead to serious erosion problems; hence he is alert to avoid most of them by exercising good judgment. These guides may prove useful in locating roads, in strengthening measures for controlling sediment on new roads, and in controlling sediment flow from existing roads.

LOCATING LOGGING ROADS

When these guides are used in locating a road, they furnish a checklist for determining whether any part of the road is likely to be too close to a lower lying site that needs protection from sediment. The following example illustrates how these guides can be applied to a given set of conditions. It also illustrates the flexibility possible in their application.

Determining Spacings of Cross Drains

Assume that a proposed road having a 4-percent grade is being located between two points

on a south-facing slope characterized by soil derived from hard shale. Assume further that the proposed location traverses the lowest one-third of the slope, which has a steepness of 40 percent above the location. Soil derived from hard shale is classified in group 1 (table 1). In 83 percent of cases, an 80-foot spacing is required on soil group 1 to prevent rill and gully erosion deeper than 1 inch on the road surface (table 2).

Installation of cross drains 80 feet apart without regard for other circumstances is not implied. Obviously, if the road exposes a perennial seep, if a skid trail enters the road, or if the cross drain would fall on a deep fill section, good judgment would dictate altering the spacing.

Determining Widths of Protective Strips

In addition to the previous assumptions made about the proposed road, let us assume that the road is to be 14 feet wide, has a 30-percent slope below the centerline, and extends through a stand of timber marked for clear cutting followed by broadcast burning of the slash. Determining necessary width for the protective strip requires several preliminary steps, as follow.

Step 1. First to be determined is what kind of obstructions to sediment flow may be expected on such a site. Table 5 shows that logs are the dominant type of obstruction here.

Step 2. Greatest average spacing of these logs to be expected is 9 feet (list on p. 19).

Step 3. Under these conditions, the protective strip should be 72 feet wide (table 3).

Step 4. However, adjustment must be made for the soil type at the location, which is in group 1. Instruction 1 following table 3 shows that 10 feet must be added to the width shown in the table; this brings total width to 82 feet.

Step 5. Further adjustment must be made for the 80-foot spacing of cross drains. Instruction 2 for table 3 indicates addition of 5 more feet for a new total width of 87 feet.

Step 6. Longest distance from road shoulder to first obstruction on a 14-foot road having a 40-percent upper slope and 30-percent lower slope is 19 feet (table 4); this requires adding 16 feet to width of the strip (instruction 3 to table 3), bringing the total width to 103 feet. This width of protective strip from the centerline should contain sediment movement downslope from cross drains on this section of road.

STRENGTHENING MEASURES FOR CONTROL OF SEDIMENT

Frequently roads have to be located close to streams. You may find that certain stretches of

these roads, when completed, are closer to streams than the widths of protective strips needed to stop movement of sediment. Under such circumstances, you may recommend use of any or all of several more intensive measures for stopping sediment safely within these narrower protective strips.

Continuing with the previous example of road location, in which the estimated required width of protective strip below the road centerline is 103 feet, assume that the actual distance from center-line to streamside is only 50 feet. The predictable sediment movement can be controlled within this 50-foot protective strip if you use the following intensive measures for control.

Step 1. You can reduce distance to the first obstruction from 19 feet to zero by scooping out depressions or installing logs at outlets of cross drains to slow the movement of all sediment and to trap some of it. This will decrease required width of the protective strip 16 feet; that is, to a width of 87 feet from centerline (table 3, instruction 3).

Step 2. Remember that protective-strip widths listed in table 3 are for roads on which it is not planned to maintain sediment storage capacity at least every 3 years. Hence, width of the protective strip in this example can be decreased another 24 feet, or to 63 feet, by installing new obstructions or by renewing storage capacity of existing obstruc-tions when the road is no more than 3 years old.

Step 3. Spacing between obstructions can be reduced by installing additional logs between those already on the ground. Reduction of space between obstructions from 9 to 2 feet will further reduce necessary width of the protective strip 14 feet (table 3); that is, to 49 feet from centerline.

You can compute the total number of obstruc-tions needed for any given average spacing by using the equation:

$$N = 1 + \left[\frac{(P - \frac{R}{2}) - I}{OS}\right]$$

in which N = number of obstructions needed
P = width of protective strip from centerline
R = road width
I = distance from road shoulder to first obstruction
OS = average spacing between obstructions.

The total number of logs (N) needed to effect 2-foot obstruction spacing in this example after the initial obstruction distance has been reduced to zero is

$$1 + \frac{(49-7) - 0}{2} = 22 \text{ logs}.$$

The exact number of additional logs needed can be determined after the road is built and at the time

cross drains are located; then the number of logs on the ground can be counted. Under these conditions, location of the centerline for the proposed road as close as 50 feet from the stream would be safe if all the prescribed control measures were applied.

If necessary, width of the protective strip below the centerline in this example could be reduced still further by applying these additional measures for sediment control.

Step 4. Reduce spacing of the cross drains from 80 feet to 30 feet. This will reduce required width of the protective strip another 5 feet; that is, to 44 feet (table 3, instruction 2).

Step 5. Spread mulch and establish plant cover on the fill slope as soon as possible. A cover density of 70 percent, for example, will reduce required width of the strip another 7 feet, that is, to 37 feet (table 3, instruction 4).

Step 6. Reduce width of the road from 14 feet to 12 feet. This reduces required width of the strip 1 foot, or to 36 feet.

If the centerline of the road is less than 36 feet from the stream, little can be done to prevent sediment from reaching the stream. The most desirable solution in this circumstance would be to relocate the road centerline more than 36 feet from streamside. If this is not feasible, then use these

measures for decreasing the protective strip width from 103 to 36 feet; at least this will greatly reduce the amount of sediment that will reach the stream.

CONTROLLING SEDIMENT ON EXISTING ROADS

Where logging roads have been located and built without benefit of guides for location and construction, the guides developed in this study may be applied to determine whether sediment from cross drains can be controlled adequately by existing protective strips below these roads. You can determine this by computing the width of the strip required under existing watershed and road conditions and then comparing this width with the actual width of the existing strip. The following example illustrates the application of these principles.

Assume that a 16-foot logging road having a 2-percent grade has been built on loessial soil across a north-facing slope 100 feet above a small stream. Assume further that the gradients of the slopes above and below the road are 60 percent and 50 percent, respectively, and that the lower slope is covered by a dense stand of timber not scheduled for cutting.

Step 1. Note that loess is in soil group 6 (table 1).

Step 2. Enter table 2 for 2-percent road grade, soil group 6, north exposure, lowest one-third

slope position, and 60 percent upper slope steepness. For this combination, cross-drain spacing of no more than 49 feet is required.

Step 3. Stake the cross-drain locations, using good judgment to insure that, insofar as possible, the drains empty onto stable fill sections on or below which standing trees are obstructions. Consider and establish each cross-drain location individually.

Step 4. Determine the distance to the first obstruction in either of two ways. One is to estimate this distance (from table 4), which is 28 feet for the road and slope conditions assumed in this example. The other is to measure or estimate the distance along a 2-foot-wide transect oriented directly downslope from the staked location of the cross-drain outlet to the nearest major obstruction. Assume, for this example, that the measured distance to the nearest obstruction is 13 feet.

Step 5. Determine the spacing between obstructions in either of two ways. One is to select the approximate maximum spacing distance (tabulation on p. 19); in this example it is 11 feet for trees. The other is to extend the 2-foot-wide transect across the existing protective strip to the edge of the stream, recording the number of trees you encounter along the transect. You can then compute the average spacing of trees by using the equation:

$$OS = \left[\frac{T-I}{N-1}\right]$$

in which OS = obstruction spacing
T = total transect length downslope from road shoulder
I = initial obstruction distance from road shoulder
and N = number of obstructions on the transect.

If you assume in this example that the latter alternative was selected and that within the total transect length you counted 12 trees, the average spacing (OS) is computed to be $\frac{100-13}{11} = 8$ feet.

Step 6. Where the dominant type of obstruction is trees spaced an average of 8 feet apart, the protective strip should be 95 feet wide (table 3).

Step 7. To this add 24 feet because the soil is in group 6 (table 3, instruction 1).

Step 8. The 49-foot cross-drain spacing (step 2) requires addition of 2 feet to the protective widths in table 3 (instruction 2).

Step 9. If distance to the first obstruction is 13 feet (step 4), 10 feet must be added to widths shown in table 3 (instruction 3).

Step 10. Now estimate density of the fill slope cover immediately downslope from the staked locations of the cross-drain outlets. Assume here that for a particular cross drain the density of fill slope cover is 50 percent. This amount of cover permits reduction of 5 feet from the standard distances in table 3 (instruction 4).

Step 11. Note that the additions shown in steps 6 through 10 above result in 126 feet of protective-strip width from the road centerline at the particular cross drain.

Since the actual width of the protective strip is 26 feet narrower than the required width, probably it will not prevent all sediment from reaching the stream. Hence, intensified control measures similar to those described above (pp. 25-29) are necessary at this location to reduce the probable sediment movement distance to less than the 100-foot width of the present strip.

INSTALLING DEVICES TO CONTROL EROSION AND SEDIMENT FLOW

Mechanical measures or construction procedures are needed on logging roads to reduce soil erosion on road surfaces and fill slopes. Some of these prevent large quantities of water from accumulating on road surfaces by diverting water off the roads at specified intervals. Others prevent erosion of fill slopes and unstable natural slopes below roads by preventing water from reaching these slopes or by conveying water from road surfaces over these slopes to stable ground or to stream channels. The general specifications for installing these measures follow.

MEASURES FOR DIVERTING WATER OFF ROAD SURFACES

Rolled Grades

The preferred method of installing road surface drainage is to construct gentle rolling dips into the roadbed as the road is built (fig. 6A). This is called "rolling the grade." In constructing rolled grades it is essential that the dips be truly dips having an adverse slope on the downroad side. Drainage bottoms of the dips should slope gently downward from the toe of the road cut to the shoulder of the fill.

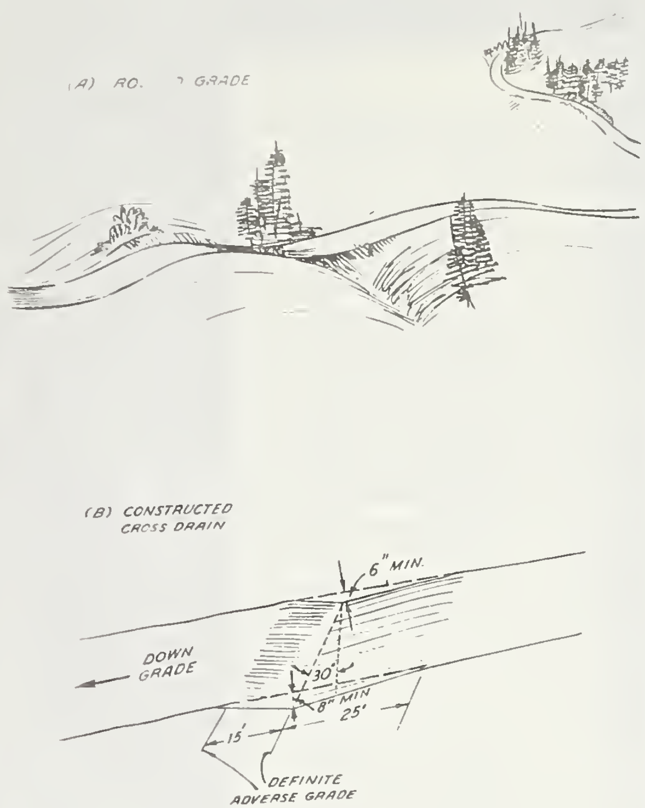

Figure 6.--Water diversions: A, rolled grade and B, constructed cross drain.

Cross Drains

Another effective method for diverting water off road surfaces is to construct cross drains in the roadbed immediately after logging and before the first fall rains or before the first winter. On roads open to passenger auto travel, cross drains must be designed to permit travel by modern sedans at speeds of 10 to 15 miles per hour. This requirement is met by cross drains having the following specifications (fig. 6B):

1. Excavated into the roadbed to minimum depths of 6 inches next to the cut bank and 8 inches at the road shoulder, with a definite adverse grade on the downroad or downgrade side of the cross drain.

2. Excavated material spread on the roadbed below the cross drain to a depth of not more than 3 inches.

3. Extending the full width of the road so that water in drains flows downhill from the toe of the cut bank to the road shoulder.

4. Tied into the cut bank at the upper end of the cross drain.

5. The long axis of the cross drain forming an angle of not less than 30° with a line across the road perpendicular to the centerline.

Open-top Culverts

An open-top culvert is essentially a cross drain constructed of wood or sheet iron (fig. 7). It should be installed according to the same general specifications used for regular cross drains. Open-top, culverts are suitable for use on secondary administrative roads but not for log haul roads.

Outsloping

Outsloping is simply uniformly grading the surface of a road so that it slopes downward across the road from the toe of the road cut to the road shoulder (fig. 8). All outsloped roads should have diversions in low sections to prevent the accumulation of water during wet weather. Outsloping is preferable for use on contour roads only.

Figure 7.--Installing an open-top culvert.

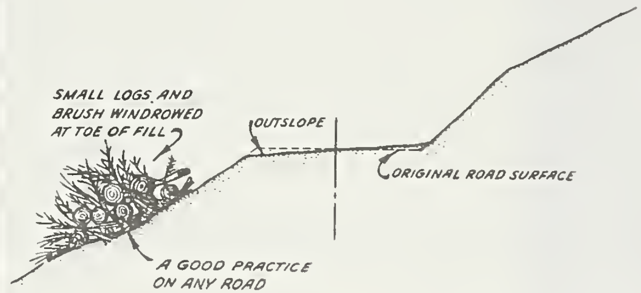

Figure 8.--Outsloping of contour roads.

PROTECTING FILL SLOPES AND UNSTABLE NATURAL SLOPES

Berms

Berms are earthen or soil cement dikes constructed along the shoulders of roads to prevent road surface water from draining onto fill slopes or unstable natural slopes. They must not be removed or damaged during road maintenance or snow removal. Berms should be constructed at least 30 inches wide at the base, 8 inches high, and 6 inches wide at the top (fig. 9).

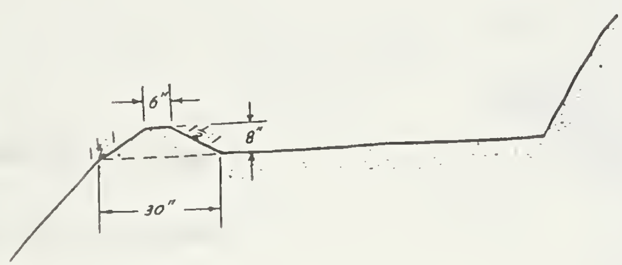

Figure 9.--Berm specifications.

Down Spouts

Down spouts are flumes, either open or enclosed, that convey water from the outlet of a road surface drainage structure downhill over fill slopes or other unstable areas to a stream channel (fig. 10). Their purpose is to prevent erosion of unstable slopes below roads by water diverted off road surfaces. They can be made of G.I. culvert, 1/2-round G.I. culvert, rock, masonry, soil cement, or treated lumber. It is important to install a concrete or rock apron at the lower end of down spouts to slow the water and prevent gouging of the stream channel.

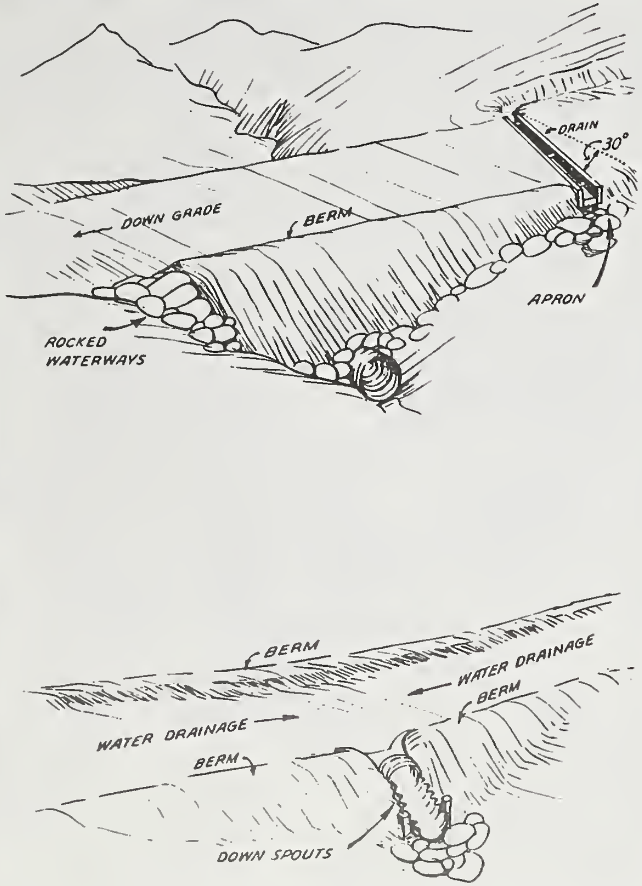

Figure 10.--Berms and down spouts to protect fill slopes.

FIFTEEN KEY RULES FOR REDUCING EROSION ON LOGGING ROADS

LOCATION AND DESIGN

1. All other factors being equal, roads located on south- and west-facing slopes require more intensive measures for preventing erosion than roads on north- and east-facing slopes.

2. Keep roads far enough away from streams.

3. Hold to low road grades.

4. Build the narrowest road that will do the job consistent with safety.

5. Build water drainage structures as part of the road construction.

CONSTRUCTION AND MAINTENANCE

1. Complete the grading and drainage on all sections of newly built road before fall rains begin.

2. Surface all roads built on highly erosive soils.

3. Do not allow low point of grade break to occur on deep fills if you can avoid it.

4. Leave berms on all deep fills.

5. Leave berms on climbing roads except at drainage outlets.

6. Construct down spouts over unstable fills and unstable natural slopes.

7. When maintaining roads, leave the toe of the cut slopes and the berms intact.

8. Where necessary, alter the spacing of surface drainage structures enough to spill the water on stable areas.

9. Install drainage diversion on outsloped roads.

10. Windrow unmerchantable logs and slash from road right-of-way timber along the toe of the fill slopes.

GUIDELINES
FOR ROAD CONSTRUCTION ACTIVITIES
IN IDAHO BATHOLITH SOILS

RISK ANALYSIS

LOCATION

DESIGN

CONSTRUCTION

MAINTENANCE

U.S.D.A. FOREST SERVICE

REGION 4

FEBRUARY 1982

APPROVED BY:

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GUIDELINES

FOR ROAD CONSTRUCTION ACTIVITIES

IN IDAHO BATHOLITH SOILS

Table of Contents

Chapter 1

INTRODUCTION TO ROAD CONSTRUCTION ACTIVITY GUIDELINES

THE IDAHO BATHOLITH

Road construction activities in the Idaho Batholith involve shallow, coarse textured soils resting on steep slopes and overlying granitic bedrock which is in varying stages of chemical and physical weathering. Rock fracturing and extensive joint planes influence the structural behavior of cut and fill slopes and dictate many of the location and design procedures. Sparse ground cover exposes the friable soils to high intensity storms and the accompanying sediment transportation. Batholith soils may also be susceptible to extensive erosion whenever surface water is concentrated by means such as road drainage ditches and culverts. Shallow subsurface flow can also be intercepted, changing the natural water movement pattern.

The Idaho Batholith comprises an area of approximately 16,000 square miles, located in the central portion of Idaho. The intrusive, igneous complex has weathered into numerous deep drainages with steep side slopes averaging 60 percent and, in many cases, exceeding 70 percent. The Idaho Batholith is a member of a chain of batholiths extending north and south along the western portion of North America, including batholitic areas in California, Nevada, and Washington. National Forest lands cover most of the Idaho Batholith and the adjacent border zones in Montana. Five National Forests in Region 4, the Payette, Boise, Challis, Sawtooth, and Salmon, share water and soil protection problems with the Clearwater, Nezperce, and Bitterroot National Forests of Region 1.

THE NEED FOR GUIDELINES

Forest Service concerns over the reduced land base available for timber production, resulting from land management planning and the RARE I and II process, prompted a Washington Office multifuctional activity review of timber harvest and related road construction activities in Regions 1 and 4. The review was conducted in June 1979, with heavy emphasis on the Idaho Batholith area. An action plan corresponding to the review findings was developed and assigned to Regions 1 and 4 for implementation. The Regional Forester of Region 4 assigned the Director of Engineering the lead responsibility for accomplishing the tasks involved in Item 20 of the action plan. Participating involvement was to include Soil and Water Management and the Idaho Batholith Forest Supervisors. The concern for land stewardship and the need to protect sensitive resource values also suggested the need for road construction activity guidelines.

Item 20 stated a specific task of developing guidelines for locating, designing, and constructing roads in Idaho Batholith soils and identifying a risk analysis procedure for activities involving major soil disturbances. Utilization of design criteria from the Horse Creek and Silver Creek studies was also suggested. The activity review emphasized the concern for soil and water resource protection.

Although the review noted many excellent examples of resource protection in road construction, some inadequate measures were noted in the geotechnical investigation areas of soil classification and the determination of subsurface conditions to ensure structural stability. Some projects reviewed displayed weaknesses in the design or construction process, such as inadequate use of drainage dips and culverts, erosion on unsurfaced roadbeds with steep gradients, excessive use of side cast construction, and underuse of compaction. Inconsistencies between Forests in the use of good design practices was a key point of the review. Several incidences of a good practice being used on one Forest, but not on an adjacent one, indicated a need for communication and an awareness of the "Best Practice" procedures being used throughout the Idaho Batholith.

The adequacy of soil and water resource protection for maintenance and enhancement of water quality and fisheries habitats was stressed in the activity review. Although no significant soil or water resource damage was observed in the five Forests visited, the need for awareness of water quality and fisheries has been stressed in the guidelines with a goal of improved protection and minimized potential for resource impact.

The guidelines and the accompanying approach to risk analysis can serve as the communication medium to identify those procedures in use throughout the Idaho Batholith area which have proven successful in soil and water resource protection. Soil similarities and similar erosion problems in other batholitic areas of California, Nevada, and Washington offer additional practices which can be applied in the Idaho area.

THE GUIDELINES

Guidelines for location, design, construction, maintenance, and a basic risk analysis approach have been developed for road construction activities in the Idaho Batholith. The guides stress soil and water protection, but recognize road utility and purpose as important management concerns. There are some natural overlaps between the guides which tend to reinforce the benefits of the "Best Practices" and emphasize the need for coordination between each step of the road development process. The concept of risk analysis must be actively present in the planning process before it can be utilized in location and design. The risk analysis process, identification of hazards, calculations of risk, and risk assessment, will involve many disciplines. Each discipline must contribute to the process. A basic approach to risk analysis has been developed instead of a more extensive program requiring specialized skills, hard-to obtain input, and lengthy lead time. The basic approach does not preclude the use of specific methods of gathering and applying field information or risk analysis processes which may be available to a Forest or those being developed for future application.

The guidelines are intended to be used as a compendium of best practices that have been successful in the Idaho Batholith soils or in areas with similar conditions and problems. The use of each item in the guides must be evaluated on its own merit and only the appropriate practices applied to

a specific project. The guidelines are not a panacea for success, but serve as a useful checklist and a format for responsive engineering to the sensitive nature of the Idaho Batholith.

The guidelines speak directly to system roads, but they also contain good practices for temporary roads constructed by the timber purchaser under timber sale contracts which are not under the control of specifications. Temporary roads must also be responsive to resource protection which can usually be accomplished under the timber sale C clause R4-C5.1-Authorization. If the situation is such that positive controls are needed, a specified road constructed to required specifications may be in order.

PARTICIPATION AND INPUT

Representatives from the Payette, Boise, Challis, Sawtooth, and Salmon National Forests were instrumental in defining the specific practices which should be considered in the road construction process. The on-the-ground expertise of the Forests was combined with research findings of the Intermountain Station representatives and the resource protection needs of Soil and Water Management and Wildlife Management to develop the "Best Practice" concepts of the guides. A guideline for maintenance was added to ensure continuing resource protective measures throughout the life of the road.

It became an obvious conclusion, as the discussions and writing proceeded, that there are fewer construction activities unique to the Idaho Batholith soils than first anticipated. Most of the practices can and should be applied to all roads with similar soil characteristics, steep side slopes, and common environmental conditions. The uniqueness in the Batholith is the sensitivity of the area and the greater degree of potential damage to soil, water, and fisheries from road performance failures. The acceptable margin of error is much smaller, therefore, requiring full consideration and application of all measures which will maximize resource protection.

The guides do not cover all road building methods, procedures, and requirements needed for road construction activities in the Idaho Batholith. The primary goal was to collect, evaluate, and organize, in a written document, proven practices which will reduce erosion and maintain slope stability. Written information on the Horse Creek and Silver Creek studies was not available, but usable input from the ongoing studies was obtained through Intermountain Station and Boise National Forest representatives.

The guideline concept, as initiated by this document, should remain flexible in format and open to correction and improvement. Additional or new practices which come to light in the future should be incorporated in the guides, to prevent good ideas and practices from remaining isolated on one Forest or District. A secondary benefit or spinoff from the guide development process was the verbal sharing of ideas, procedures, and results among the Batholith Forests, the Regional Office, and the Intermountain Station. This practice should be encouraged and continued whenever possible.

Chapter 2

RISK ANALYSIS

For Erosion and Sedimentation from Road Construction Activities In Idaho Batholith Soils

INTRODUCTION

Soil-disturbing activities in the Idaho Batholith have been of major concern to land managers for many years. Runoff events which occurred during the rain-on-snow situation of 1964-65 and the rapid runoff experienced in 1974 resulted in damage viewed by most managers as being excessive. Damage to transportation facilities in terms of roadway failures required large capital expenditures for repair. Of greater significance was the damage done to watershed and fisheries resources. Land disturbing activities inherently involve elements of high risk in terms of slope failure and surface erosion which affect water quality, sedimentation rates and the aquatic habitat. Adverse environmental impacts from land use activities in the Idaho Batholith can be minimized if the risks of instability are recognized, analyzed systematically, and considered in the design and planning process.

DEFINITIONS

Risk analysis and the associated terms have different meanings for different people. Therefore, a logical starting point for the discussion of risk analysis is an explanation or definitions of some of the specific terms used in the guide. For the purposes of this guide, the following definitions will be used:

<u>Risk</u> - the probability of an unacceptable consequence.

<u>Probability</u> - the measured chance or uncertainty that an event will occur.

<u>Consequence</u> - something produced by a cause or necessarily following from a set of conditions.

<u>Unacceptable</u> - unwanted, received without consent.

<u>Analysis</u> - an examination of a complex, its elements, and their relations.

Paraphrasing these definitions, <u>risk analysis becomes the examination of the causes and probability of occurrence of unwanted events</u>. The definition of risk analysis infers that if there is certainty there is no risk. Decisions involving risk need to consider uncertainty, causes, and consequences. Value judgments may be needed to determine acceptability.

<u>Hazards</u> - Hazards are associated with causes and, by definition, are a source of risk, usually a physical entity or condition.

Mitigation - Mitigation is the lessening of risk. Mitigating actions include both investigation and stabilization measures. Investigation addresses uncertainty and stabilization measures address causes. Investigation alone does not affect probability, but the actions taken after investigation may result in less possible causes or risk.

THE RISK ANALYSIS PROCESS

The risk analysis process can be broken down into the following stages:

Stage 1. Identification of hazards.

Stage 2. Calculation of risk.

a. Determining operative conditions and effects.

b. Estimating probabilities.

c. Evaluating mitigating measures.

d. Reevaluating probabilities.

Stage 3. Risk assessment.

a. Evaluating unacceptability of consequences.

b. Evaluating benefits of risks.

c. Evaluating mitigation constraints.

Information required for risk analysis is multidisciplinary. Geologists, geotechnical engineers, location engineers, soil scientists, fisheries biologists, and hydrologists may all have participation in the identifcation of stability hazards. These hazards may include probable maximum precipitation events, landslides, groundwater occurrences, or construction features. The specialists involved in Stage 1, preliminary stages of hazard identification, may also be involved in later analysis stages to calculate risks. The design engineering is mostly involved in evaluating and designing mitigation measures. The other specialists can also provide information regarding consequences and effects of erosion, instability, and off-site impacts to fisheries, aquatic habitat, and water quality. In some cases, a drainage-wide risk analysis may be necessary to identify cumulative impacts to fisheries from multiple road activity.

In identifying hazards or calculating risk, it is not sufficient to consider only physical parameters. Human factors, such as misinterpretation of information, organizational inadequacy (compatibility of design and construction) and deviation from specifications, must be considered.

Probability estimates may be either objective or subjective. The objective probability of an event is the theoretical estimate or the observed relative frequency of occurrence of that event. Subjective probability is a

measure of an individual's personal confidence in the truth of some proposition and is used to communicate personal certainty or uncertainty in a particular situation.

Risk assessment primarily involves information which determines acceptability or unacceptability of impacts from activities. Benefits from risk taking can be evaluated in terms of opportunities or costs of mitigation. If no action is taken, generally, some opportunity may have been lost. The value of this opportunity needs to be specified.

The dictionary's definition of safety is "free from harm or risk." This definition of safety frequently has a narrow perspective and considers a single value rather than multiple or conflicting values. A more practical concept for engineering trade-offs states that safety is achieved if probabilities and consequences are acceptable considering the benefits.

Reduced mitigation cost can be considered a benefit attributable to taking risks. The cost-effectiveness of mitigation measures should be evaluated. Unlimited resources generally are not available for complete mitigation.

The NEPA environmental assessment document should provide design engineers with guidance as to acceptability of impacts. Some risk calculation is inherent in this assessment.

Risk analysis is merely a means to an end, the end being a decision or an action. Analysis should precede decisionmaking rather than being used as subsequent justification. Risk analyses or processes do not make decisions. People make decisions and are responsible. Analysis and process are only tools to be used in arriving at decisions.

During early planning stages, information is at a minimum and uncertainty is greatest. At this level of decisionmaking, future activities should be contingent upon receipt of additional information such as site specific conditions or mitigation feasibility. Planning decisions should focus on formulating risk acceptance criteria rather than acceptance or rejection of activities. Planning decisions based upon the identification of hazards alone frequently defer risk taking to a future time when no risk-free alternatives exist. Deferment could compound impacts.

A BASIC APPROACH TO RISK ANALYSIS

The details and sophistication of risk analysis processes can be highly variable; however, a basic approach exists. A risk analysis has been performed if the following questions are addressed:

What hazards exist?

What are the operative conditions?

What are the uncertainties?

What are the consequences?

What are the mitigating measures?

What are the benefits?

An analysis that considers all of the above questions except uncertainty and benefits is classified as a hazard analysis. Table 1 presents examples of some of the typical elements of a hazard analysis for road construction in the Idaho Batholith. The consequences described, erosion and mass instability, are of secondary importance. It is the effect of erosion or instability on land use, fisheries habitat, and visual values that is of primary importance. These consequences are site specific. Road construction features such as culverts can themselves be hazards and should be analyzed as such.

A PROPOSED PRELIMINARY HAZARD ANALYSIS PROCEDURE

The Regional Forester, Region 4, has specified that the Land Systems Inventory shall be used as the basis for all land and resource planning in Region 4. When mapped at the landtype level, general conclusions can be formulated regarding potential hazards inherent within the mapped units. These conditions, usually contained in the Soil-Hydrologic Reconnaissance Report, are expressed in terms of surface erosion, mass failure potential, trafficability, revegetative potential, etc. Through proper use of this and other available information, a rational process can be utilized to evaluate the potential hazard for any proposed management alternative involving land disturbance. Such a process has been developed by researchers of the Intermountain Station in conjunction with several National Forests. The process is documented in the joint Region 1 - Region 4 publications titled "Guide for Predicting Sediment Yield from Forested Watersheds," dated October 1981, and the companion document, "A Method for Predicting Fish Response to Sediment Yield," scheduled for publication by April 1982.

Although the landtype descriptions contain interpretations of inherent hazards, the degree to which these hazards may result in failure or environmental degradation must be determined by some analysis technique. The magnitude or consequence of surface or mass erosion depends entirely upon the degree to which they affect resources. In most recent land management planning efforts, an attempt has been made to describe these consequences in terms of effects on water quality, stream sedimentation, and aquatic environments.

The process defined in the "Guide for Predicting Sediment Yield from Forested Watershed" is partially responsive to a risk analysis technique as follows:

1. Includes in appendix C a process for evaluating inherent hazards or stability in any landtype (hazard identification).

2. Estimates the landtype's ability to transmit sediment to a stream course (cause and effect).

3. Estimates a natural state of sediment yield within the watershed (baseline of acceptability).

4. Estimates the relative effects a proposed management activity will have in changing the natural state of sediment yield (consequences).

5. Estimates the relative degree of change or effect that may be expected from a proposed management activity (magnitude).

6. Evaluates relative effects through the introduction of mitigating measures (consequence manipulation).

7. Permits translation of development options to economic terms.

LIMITATIONS AND CONSTRAINTS

As with any analysis procedure utilized for complex natural ecosystems, some limitations exist. The technique itself is most appropriate at the Forest and project planning levels for environmental assessment purposes, and should not be used for project design. Although some generalized design criteria may be developed from landtype information, more detailed site specific data may be needed for design purposes. This is particularly true where high hazard situations are encountered. The analysis process will, however, assist the manager in determining where additional investigation may be needed and of what kind. As more detailed information is obtained, on a specific landslide for example, more complete risk analysis techniques may be more appropriate. Another example where additional investigation information may be necessary is the area of endangered or sensitive fisheries such as anadromous fish water quality values.

In its present form, many of the assumptions pertaining to sediment yield and delivery efficiencies, etc., are empirical in nature. For this reason, the analysis of hazard and estimation of consequences and magnitudes should be used in a relative manner. Continued research and modeling of erosional processes, however, could eventually expand the technique to display consequences in more absolute terms.

The most limiting constraint, however, is in the landtyping system itself. The degree to which Forests within the Idaho Batholith are mapped varies greatly. To utilize the technique, mapping must be done to the landtype level. This constraint can be overcome as long as managers are committed to allocating the financial and manpower resources needed to accomplish the task. The activity review report of June 1979, pertaining to timber harvest and road construction activities, also recogized this situation. Action items No. 2 and 3 of that report direct Regional Foresters to accomplish this task.

Of equal concern is the terminology, mapping techniques, and interpretations used in the landtyping process. It is essential that a standardized approach and common language be developed for the Land Systems Inventory. This will require a major effort as significant differences exist between Forests. Currently, this is perhaps the greatest single constraint to

extending the use of the "Guide for Predicting Sediment Yield from Forested Watersheds" model. Again, the activity review report recognized the importance of this task, and action item No. 1 addresses it.

The "Guidelines," as published, have some deficiencies that need correction with time and use to enhance their usability as an analysis procedure. Individual landtypes inherently involved different levels of hazard for both surface and mass erosion. The procedure for estimating management-induced effects is not sensitive to these variables. Estimates for the natural condition and slope delivery efficiency both account for these differences, and the management-induced effects should as well.

In addition, variations in effects caused by differences in climatic events are not considered. Assumptions are based on static climatic conditions which obviously never occur. Climatic variables could appropriately be introduced as probabilities of change to the static condition effects.

ACTION REQUIRED TO IMPLEMENT

Both the "Guide for Predicting Sediment Yield from Forested Watersheds" and "A Method of Predicting Fish Response to Sediment Yield" provide methods of prediction; however, the following actions are needed to enhance their utility:

1. Develop a standardized approach to mapping, describing and interpreting units in the Land Systems Inventory (action item No. 1 of the June 1979 Activity Review Report on Timber Harvest and Related Road Construction).

2. Complete Land Systems Inventory mapping to the landtype level on all Idaho Batholith Forests. The responsibility for accomplishment will have to rest with the individual Forest Supervisors with direction from the Regional Forester.

3. Key the "Percent Reductions in Erosion Factors for Mitigating Measures" to those best management practices defined for road location, design, construction, and maintenance. Modify the percentages in accordance with the Horse Creek and Silver Creek findings.

4. Revise the "Guidelines for Predicting Sediment Yield" document to include the use of landtype hazard ratings in determining management effects for surface erosion.

5. Test the sediment yield prediction technique to verify the procedure, assumptions, and acceptability for general use.

6. Develop training to transfer the available technology among Forests within the Idaho Batholith.

Table 1

Hazards	Operative Conditions	Mitigation Measures	Consequences
Landslides	Excavation and fill geometry. Mass shear strength. Groundwater. Surface drainage.	Decrease driving forces. Increase resisting forces. Avoid location	Mass instability
Shallow soils	Runoff intensity and duration. Soil depth. Soil permeability.	Avoid location. Sediment retention. Surface water control.	Mass instability, Erosion
Ground water	Excavation and fill geometry. Pore pressure	Drainage. Avoid location.	Mass instability
Culverts	Runoff intensity and duration. Blockage. Construction.	Sizing. Maintenance. Inlet protection. Avoid location. Inspection.	Erosion
Drainage ditches	Runoff intensity. Blockage. Soil tractive resistance. Slope. Discharge location.	Sizing. Armoring. Energy dissipation. Maximum slopes. Maintenance. Avoid location.	Mass instability, Erosion

Chapter 3

GUIDELINES FOR LOCATION OF ROADS IN IDAHO BATHOLITH SOILS

ASSUMPTIONS AND ISSUES

The guidelines and procedures shown are based on the premise that the intended uses of the road, both short and longterm, are clearly understood and have been documented through the transportation planning process. It is also assumed that prior to road location, standards have been determined, based on land management plans, environmental assessments, and trade-off evaluations which include safety, cost, and impacts on the land and resources.

The logging system/transportation issues should be resolved before extensive effort is directed into road location work. The guidelines assume that the planning process has included the coordination of the required road network with the selected logging system.

Road locations must be made by qualified people. Experience has shown that a highly qualified locator can reduce problems, costs, and environmental impacts for future road construction. A good location is essential for a good road design.

The primary problems with the roads located in the Idaho Batholith are related to excessive erosion and mass instability. Most erosion and mass instability problems are related to hydrologic conditions. Sources of water are rain, springs, streams, and snowmelt, which may be encountered as subsurface or surface water.

PRELIMINARY INVESTIGATION

Alternate routes should be located on a topographic map or resource photo during the early stages of the environmental assessment. Once this is done, the routes can be equated to soil and hydrologic studies of the area. Many major hazard areas can be determined and avoided at this point. The possibility of mitigating measures can be studied for inclusion in the design.

WATER MANAGEMENT CRITERIA

Water management criteria for roads must be determined early. A determination should be made to concentrate or disperse the water. For some roads, a combination of concentration and dispersion may be used. The criteria will vary by soil type or by slope aspect.

V-SHAPED VALLEYS

Traversing V-shaped valley bottoms should be avoided if possible. It is usually difficult to keep road debris and sloughed material out of the valley bottom.

STEEP SIDE SLOPES

Locations on slopes steeper than 55 percent tend to be unstable and increase the chance of mass failure in both cut and fill slopes. Full bench cuts should be considered on these steeper slopes, which will necessitate hauling the excess material to a fill or waste area.

ALTERNATE ROUTES

Alternative routes should be considered when unstable areas or high hazards are encountered or where there is a lack of filter strips near streams. When it is necessary to go through a hazardous area such as areas of mass movement, high water table, etc., a special indepth study utilizing geotechnical assistance may be needed. (See R-4, 7170 Materials Engineering "Outline for Geotechnical Investigations of Roads" and "Geotechnical Investigation Check List.")

GRADE

Preferred grades are usually 6 percent or less. However, occasionally the use of steeper grades may reduce overall resource impacts. When grades are to exceed 8 percent the full ramifications should be considered. Such things as special surface treatments, asphalt or aggregate, and special drainage requirements should all be weighed and evaluated. The rational decision for exceeding the 8 percent should be recorded in the environmental assessment document. In flatter country or on contour locations, the grade should be rolled to control surface water and prevent it from concentrating or changing the natural drainage patterns. Where possible on most low standard roads, keep uniform sustained grades greater than 4 percent to less than 800 feet in length. This helps to get the water off the road.

DRAINAGE DIPS

Drainage dips are of the utmost importance. If drainage dips are to be used, they should be considered during location. Specific sites for dips should be identified. It is necessary to allow for the dips, otherwise the road will become too steep through portions of the dip section. Spacing of dips should be based on the velocity of water and particle size. However, the following chart may be used when particle sizes are unknown:

% Grade	Spacing in Feet
0-1	*
1-2	500-600
3-4	400-500
5-6	300-400
7-8	250-350

(This chart originated on the Salmon N.F.)

*Grades of less than 1 percent are not recommended because of ponding and water movement problems. These problems are often compounded because of construction tolerances.

Look for natural dip areas when establishing the location grade.

FILTER STRIPS

Filter strips of undisturbed land can be left between the road and the stream to reduce the amount of sediment reaching the waterway. Special attention should be given to land and vegetation for approximately 100 feet from the edges of all perennial streams to prevent sediment deposition which will seriously and adversely affect water conditions or fish habitat. Special attention should also be given to riparian area edges adjoining all annual (intermittent) streams used by fisheries. FSM 2526 - Riparian Areas should be studied for policy and protection requirements.

STREAM CROSSING

Perennial streams and most intermittent streams should be crossed at right angles. Normally, this will result in the least amount of area being taken out of the valley bottoms and the riparian zone. This also lessens the chances of siltation and pollution of the streams. Bridges and open bottomed culverts are preferable to culverts to maintain fish passage and aquatic habitat values.

RECOGNIZING POTENTIAL SUBSURFACE WATER PROBLEM

Recognizing subsurface water is one of the toughest problems in location. Some of the telltale signs to look for are:

1. Springs in area above or below the proposed alinement.

2. Different types of vegetation which indicate subsurface water. Aspen and spruce normally indicate the presence of a high water table. Sedges and various shrubs may also indicate a high water table.

3. A change of vegetation and growth patterns such as heavy green growth.

INDICATORS OF PREVIOUS SLOPE MOVEMENT

Some indicators of slope movement are:

1. Hummocky ground, old blow outs, slide areas, or slump areas.

2. Irregular non-vertical tree growth or trees not lining up vertically.

3. "S" shaped trees. Must be distinguished from similar type of growth caused by snowload and pressure.

All locators should become familiar with "Practical Grain Size, Fracturing, Density, and Weathering Classification of Intrusive Rocks of the Idaho Batholith" by James L. Clayton and John F. Arnold, GENERAL TECHNICAL REPORT, INT-2, 1972. Locators should also consult with and use geotechnical skills, such as geotechnical engineering, geology and soil science.

Chapter 4

GUIDELINES FOR DESIGN OF ROADS IN IDAHO BATHOLITH SOILS

This guide is intended to cover the known successful road design practices used in Idaho Batholith granitic soils. The guides will help minimize failures but will not solve all problems. More restrictive practices should be undertaken in areas where failures will produce unacceptable results.

DRAINAGE - Control of water is a major concern throughout design. During design it may be necessary to include insloping, outsloping, special drainage structures, oversize culverts, regular and special ditching, drainable dips, water bars, downspouts, and underdrains. These could all be used on the same road and possibly several different applications could be found in any given mile.

1. Culvert Locations

a. When possible, place in natural drainages. Also, when possible, place pipe on natural ground, especially inlets and outlets.

b. Avoid "shotgun" culvert designs. If the design requires culvert outlet to be on a fill section, flexible or rigid downspouts should be used. When rigid downspouts are used in heavy snowfall areas, burial of the pipe may be required to prevent damage or separation due to snow load.

c. In natural drainages, culvert gradients should correspond to natural grades. Cross drains (ditch relief) should be designed to be self-cleaning and have the following minimum grades in order to develop critical flow:

(1) 18" - - - 2.2%

(2) 24" - - - 1.9%

(3) 30" - - - 1.7%

Normal practice is to install crossdrains at a grade slightly steeper than the ditch grade.

d. Energy dissipaters should be placed at culvert outlets when outlet velocity is greater than culvert inlet velocity or when water needs to be dispersed. Energy dissipaters in common use are as follows:

(1) Gabions

(2) Rock Riprap

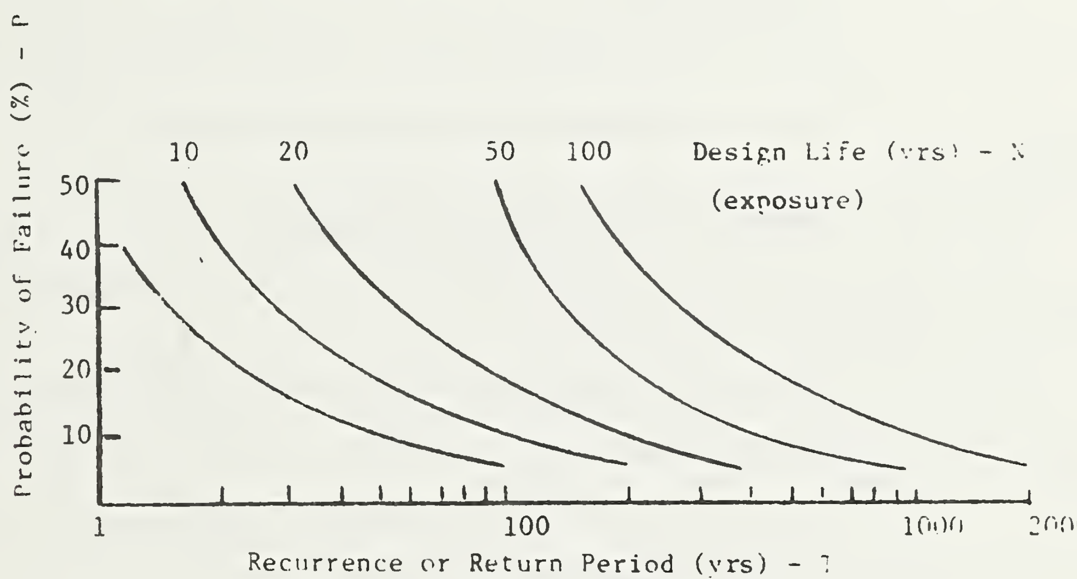
(3) Rock Blankets

(4) Metal End Sections

e. Culverts 48 inches or larger should be designed with the fill perpendicular to the stream channel, similar to building an earthen dam. This increases entrance efficiency of the culvert and reduces erosion potential at the culvert entrance. If it is not possible to use the larger culvert, protection such as flared inlets can be added.

2. Drainage Structure

a. Calculated risk should be considered in the decision process for selecting design return periods. The figure below presents probability of failure estimates for varying return periods and design lifes.



Reference: Chow, V.T., 1964, "Handbook of Applied Hydrology. McGraw-Hill Book Company, N.Y., Chap. 9, pg. 59.

$$P = 1 - (1-1/T)^N$$

P = Probability of Failure

T = Recurrence or Return Period

N = Design Life

b. Decisions accepting risk can be based upon cost-effectiveness or cost-benefit. The figure above may be transformed into a cost-benefit graph by substituting costs of constructing drainage structures for varying return periods for the respective return period plotted on the graph and considering benefits to be reductions in probability.

c. Provisions for debris passage should be made as needed.

d. Flared inlet structures may be used to increase efficiency of culvert.

e. Where possible, bridges and open bottom culverts should be of sufficient size to span existing high water marks in the channel. This reduces scour without increasing water velocity.

f. Water volume can be determined by different methods. The following are some of the acceptable methods:

(1) Stream gauges.

(2) High water marks from runoff of known return period.

(3) Emperical equations based on known drainage characteristics.

(4) Known flows on comparable drainages.

g. Streams with a heavy bed load may create culvert abrasion problems. Abrasion may be reduced by:

(1) Burying the culvert inverts below the stream channel.

(2) Adding a pipe liner.

(3) Using a different type pipe such as concrete.

(4) Installing open bottom culverts.

(5) Bridges instead of culverts.

h. Additional compaction should be used at culvert installations in through fills. Compaction for a distance of ten pipe diameters on each side of the pipe is suggested for intermittent streams. Complete valley floor fill compaction should be used when crossing a live stream. For a bridge-type structure crossing a live stream the compaction should take place over the entire valley floor fill area. Compaction should be required for a minimum distance of 25 feet on each side of the bridge structure.

i. In streams having fish populations, bridges and open bottomed culverts are preferable. Where cost is an overriding factor, culverts should be installed in such a type and manner that fish passage, through gradient and velocity, is assured.

<u>EROSION CONTROL MEASURES</u>

1. As a minimum, all fill slopes and cut slopes with slope ratios of 1:1 or flatter should be dry seeded. Seed mixtures for specific projects should be determined by District or Forest specialists.

2. In the vicinity of perennial stream crossings, extensive surface erosion control measures should be considered. Usually, extensive measures are only required for 150 feet or so beyond each creek bank. The following measures can be used to prevent erosion, but application should be as soon as possible following disturbance:

a. Mulching with straw netting.

b. Planting of shrubs and trees.

c. Placing of brush or clearing debris on fill slopes.

d. Seeding of fill slopes and rolling with sheepsfoot-type roller.

e. Placing rock riprap on embankment.

3. Low points of vertical curves (- to + grade) should be designed so they will not occur on through fills. Low points of vertical curves concentrate surface water and force drainage onto fill slopes or pond water which may saturate the fill.

4. Berms may be used to control surface water movement and prevent water from draining off the road surface onto large fills. If berms are used, they will have to be carefully located and maintained so they do not fail and compound erosion or develop excessive concentrations of surface water. When berms are used, they can often be removed by maintenance crews after fill slopes have stabilized.

5. In drainages where debris (or bulking) is highly probable, the following steps may be taken to reduce the chance of erosion:

a. Install rock lined dips adjacent to culvert locations.

b. Oversize culverts or bridges.

6. When concentrated water is removed over a fill slope or along the toe of a fill slope, provisions for slope protection should be provided. Protection may be provided by:

a. Riprap on the fill section.

b. Gabion blankets.

c. Berm drains.

d. Downspouts.

e. Asphalt or metal flumes.

f. Mulch netting and seeding.

CUT AND FILL SLOPES - Normally, small cuts and fills pose less erosion problems than larger cuts and fills. Erosion is less because of the smaller area exposed or disturbed. The failure of a small cut or fill displaces much less material than failure of a large cut or fill.

1. Slope ratios should be designed for mass stability. Mass stability may be determined by stability analysis of the soil and rock or by the use of successful practices on similar land types. Knowledge of bedrock characteristics and bedrock weathering may aid in determining stable slope ratios. Geotechnical assistance may be required in new areas or where bedrock and soil characteristics are questionable.

2. When designing fill slopes using "sidecast-end dump" construction methods, design the slope to agree with the natural angle of repose. This should aid in cut and fill quantity balancing, and reduce the overall width of finished roadway when the road is constructed to design grade. Sidecast-end dump fill slopes are not recommended for large or high fills.

3. Layer placement is recommended for fill slopes 1.5:1 or flatter.

4. When no compactive effort will be used in construction, 2 extra feet of width for slough widening should be designed into the road template.

5. Consideration should be given to full benching where side slopes exceed 55 percent. This will usually result in excavating and end-hauling throughout the steep area.

INSLOPE VS OUTSLOPE - Both insloped and outsloped templates have advantages or characteristics which make one template more suitable than the other for the conditions and desired results. The following compares the insloped and outsloped template characteristics:

1. Size - The outslope template, from toe of fill to top of slope, is slightly smaller in non-ditch sections and considerably smaller when the inslope template contains a ditch.

2. Ditches - Outsloped templates do not contain ditches, while insloped templates must provide for surface water transport and often contain a ditch.

3. Culverts - Outsloped templates do not require culverts unless there is live water or natural cross drainage, while culverts are generally required for insloped roads.

4. Berms - Are not required on either template, but are often used as an extra precaution on insloped roads to keep water from going over fill slopes.

5. Drainage of Surface Water - Outslope roads rely on dips, swales, and dispersal of water, while insloped roads concentrate water and remove it from the roadway by culverts or ditches.

6. Water Management - Outsloped templates disperse water and insloped templates concentrate water. However, traffic wear often changes the outsloped template creating unplanned concentration; maintenance is critical.

SELECTION OF INSLOPED OR OUTSLOPED TEMPLATE - Water handling characteristics of a road template are the primary factor in selection because water is the major erosive agent in the Idaho Batholith. The road template selected should generally be the one which has the least erosion potential. Both inslope and outslope can be used on a project.

As mentioned earlier, during the EA process or early planning, a determination should be made to concentrate or disperse surface water. If the decision is made for dispersal then outsloping is the desired template; conversely, if concentration of water into a natural channel is selected then insloping is the desired template.

ADDITIONAL ROAD TEMPLATE FACTORS - Listed below are factors and comments which must be considered in selection of road templates:

1. Fill Heights - As fill heights increase, erosion from water on the fills increases. On fill heights exceeding 8 feet some rilling can be expected.

2. Road Grade - When the super elevation of a curve is less than the road grade, water tends to concentrate and run longitudinally along the road instead of transverely across the traveled way.

3. Side Slope - Determines overall cut and fill heights.

4. Natural Drainage - Naturally occurring convex slopes disperse water and concave slopes tend to concentrate water.

5. Use in Adverse Weather - Outsloped roads are generally for seasonal use.

PLANS AND SPECIFICATIONS - Special project specifications should be developed as plans are being prepared. Be specific as to how the construction should take place. By bringing the special project specifications along with the plan, disagreements between specifications and drawings can be avoided. Ensure that all specification references to the plans are shown on the plans. Include in the specifications such constraints as how many miles of pioneer road can be opened. No more roads should be opened than can be built in any one field season. Also, consider any temporary drainage requirements needed for pioneer roads.

Drainage structures should be required to be installed along with the construction of the road. Don't allow the roadway to get too far ahead of completed drainage structures such as culverts, cross drains, etc. Should a job be stretched over 2 seasons, be sure to include any winterization work that needs to be done.

The specifications should provide protection for water sources involved in construction.

RAPID SURVEY DESIGN SYSTEM - The Rapid Survey Design System (RSDS) was developed to reduce the manpower required to survey and design a road and to provide a means whereby roads will better fit the ground, create less impact, or be less costly to construct. The location of a road is carefully planned and laid out on the ground by experienced locators. Care is taken to fit the line to the ground and to identify any problem areas. The RSDS uses a free-flowing horizontal alinement. Slope stakes are set from slope distances as the survey progresses. The system relates well to the sensitive nature of the Idaho Batholith soils.

Chapter 5

GUIDELINES FOR THE CONSTRUCTION OF ROADS IN IDAHO BATHOLITH SOILS

CONSTRUCTION ENGINEERING - Construction practices must maintain and enhance the safeguards developed during location and design to ensure that soil and water resources are protected during the life of the road. The same concern for protection must prevail during the construction period. Because of the sensitive nature of the erodible soils and the associated steep slopes, the margin of error is very narrow in the Idaho Batholith. The sediments are easily detached, highly mobile, and detrimental to the streams. Steep slopes and thin granitic soils which are easily saturated set the stage for slope failures which, in turn, are easily triggered by inadequate design and construction practices.

Construction personnel should become familiar with the guidelines for location and design, as well as the guidelines for construction. An understanding of specific engineering design measures should be developed and applied to road building in the Idaho Batholith soils. The project plans and special project specifications should be studied to gain an understanding of the specific protective measures designed for the project. Although most resource protection measures and special construction practices will be established in the contract or timber sale, there are some additional practices which must be picked up during construction.

Construction operations are the responsibility of the contractor or timber purchaser. This gives them the basic control over planning and operational procedures. However, the responsibility includes prudent construction practices and resource protection. Forest Service construction personnel have the opportunity and responsibility to work with and, in some cases, to direct the contractor in an effort to obtain the results expected from the project. Operational procedures for construction in the Idaho Batholith should reflect consideration of the highly erodible soils, steep slopes, and the potential for slope failure. Construction sequences, schedules of completion, and proper equipment are all important to a successful construction operation.

Construction engineering should assure that erosion and sediment transport during construction are minimized, slope stability is maintained, and roadbed soils are stabilized. The following guidelines cover some of the common areas of concern for resource protection and construction practices that have mitigating effects on erosion and stability.

CONSTRUCTION DRAINAGE AND EROSION CONTROL - The erosive agents for Idaho Batholith soils are water and gravity. These agents, in the form of high velocity surface water from storms and snowmelt, easily detach and transport the unprotected granular granitic soils. Subsurface water contributes to the soil disturbance through saturation and the resulting loss of strength of the soil mass.

The largest portion of erosion associated with roads has been observed to take place within the first 2 years, including the construction period.

Further evidence shows that significant amounts of this erosion occur when storms are encountered during the construction period. Erosion is further increased when several storms occur in rapid succession. The process of construction itself generally creates temporary disruptions to surface and subsurface water flow which become undesirable if the water flow saturates fills, roadbed soils, or erodes loose sediments. Construction operations can minimize the impact by:

1. Constructing and maintaining temporary or permanent ditches during construction. Steep V-shaped ditches generally are more susceptible to erosion than flatter V-shaped or flat bottom ditches.

2. Controlling the gradient or velocity of water moving through the construction zone. Temporary check dams or water bars should be considered. Granitic soils are easily detached and erode easily at lower water velocities than many other soils. Controlling measures should be started when erosion is observed.

3. Providing settling or desilting ponds when needed to minimize sediment entering live streams.

4. Directing water towards the ditches and not allowing it to run down the road which is under construction.

5. Directing construction drainage to natural or completed drainages as soon as possible. Intermediate settling basins should be considered if the water is turbid.

6. Using fabric, silt fences, baled straw and other methods to retain sediment on site and to direct water.

7. Keeping the installation of designed drainage structures current with construction.

8. Providing temporary berms on fills when heavy storms are anticipated.

9. Constructing fills so that they will minimize water ponding on the fill during construction.

10. Completing the road or individual sections or portions of the road to grade as soon as possible. The exposed, undrained soils under construction have a greater potential for erosion than the completed road.

11. Revegetating disturbed areas as soon as possible when called for in the contract or sale.

PIONEER ROADS - Roads built to accommodate equipment for cut and fill construction and work roads are generally not specified in a contract or timber sale. These roads do not have the benefit of engineering design and can be major contributors to erosion or slope failure in granitic soils if heavy

storms occur during construction. Occasionally these roads are not entirely obliterated by the ensuing earthwork, creating a potential problem unless some basic precautions have been taken. Each pioneer road should be reviewed to ensure that it minimizes:

1. Sediment transport which can get to live streams.

2. The practice of opening up pioneer roads far in advance of planned construction.

3. Grade, width, and length of those roads used for access which will not be obliterated by final construction. The template should provide insloping for fills and outsloping for bench sections. After use, the road should be closed and rehabilitated as appropriate for the area and the contract.

<u>CUTS AND FILLS</u> - Cut and fill construction influences both slope stability and earthwork volume. Stable slopes occur when the proper slope ratio is applied to a cut or fill. The design intent is usually to maximize the steepness of slopes, thereby reducing the earthwork volume and minimizing the exposed area created by the road. It is therefore important to construct the slope ratios as designed, oversteepened slopes increase the risk of slope failure and sediment loss to the streams. Changes in earthwork volume resulting from slope ratio changes can create an imbalance in earthwork quantities and a need to waste material in unplanned areas or borrow additional material, increasing the area of exposure. Construction personnel must be familiar with the intent of the design and committed to obtaining the contract requirements. Knowledge of the intent of the design will also help in recognizing the need for design change or field adjustment. The following items are critical to successful cut and fill construction in Idaho Batholith soils:

1. Construction staking of slopes should accurately reflect the design as specified and construction should closely conform with the staking. Oversteepened fill slopes which are built from the toe up require additional fill material. This, in turn, requires more excavation from the cut slope or the use of additional borrow. Oversteepened slopes also increase the gravitational or weight forces on the fill material, increasing the potential for downslope movement. Cutslopes, flattened more than needed for stability, expose excessive raw material to erosive forces and create additional earthwork volume which must be used in the fills or wasted.

2. The prescribed compaction of fills must be accomplished to develop the safety factors expected from a specified slope ratio. Allowing less compaction than required will reduce the safety factor.

3. Slash and other debris should not be placed in fills or covered by fill material. The immediate detriment is a reduced density of the fill and a resulting loss of strength. Vegetative decay after 5 to 10 years has been a recognizable cause of failure in the Idaho Batholith soils.

4. Slash, fill, and other debris should not be deposited in riparian areas or stream channels. This will reduce adverse impacts to fisheries and water quality values.

DESIGN CHANGES AND CORRECTIVE MEASURES - The need for design change often occurs during construction to correct inaccurate design or to adjust to unforeseen field conditions. Construction engineers have the responsibility to look for and recognize the need for design changes. The original design intent should be verified before any changes are made; however, design changes may be needed when:

1. Excessive subsurface water is intercepted.

2. Unstable slopes are encountered.

3. Large quantities of previously unexposed rock exist.

4. Unuseable soils must be wasted or unstable soils stabilized.

5. Earthwork quantities don't balance.

6. The designed surface drainage is inadequate or inappropriate.

7. Unforeseen sliver cuts are encountered.

There are many indicators that can alert a construction engineer to impending problems and the need for design changes. The indicators are easily recognizable but are not always conclusive. Additional investigations by appropriate technical skills may be needed to ensure the red lights or indicators require a design change. The following are usually indicators of pending construction problems:

1. Excessively wet surface areas.

2. Water indicating vegetation.

3. Flowing or moving subsurface water (usually near the contact of the granitic soil and parent rock).

4. Change of soils (granular to plastic, etc.).

5. Hummocky or slumping surface shapes.

6. Soil and soil conditions similar to conditions of known landslides in the area.

7. Small rock outcrops.

8. Earthwork quantities that do not comply with the design.

9. Inaccurate drainage spacing or size.

10. Bedrock in weathering class seven.

The erodible nature of granitic soils in the Idaho Batholith and the susceptibility to local landsliding dictate immediate action when corrective measures are needed. Corrective measures that will usually minimize erosion, stabilize slopes, and provide stable roadbeds include:

1. Compact the fills.

2. Waste unstable or unuseable soils in planned locations.

3. Reevaluate earthwork balance quantities. (Minimize the amount of earthwork needed.)

4. Change of slope ratios.

5. Change of road template.

6. Change of grade or alinement.

7. Stake to avoid sliver fills.

8. Adjust quantities or staking to ensure that full bench sections remain full bench. (Do not create a sliver fill.)

9. Avoid construction widening of roads.

10. Add or change drainage to handle water quantities.

11. Install interceptor drains.

12. Seek additional technical skills and assistance for major slope and drainage problems.

The corrective measures listed should not be indiscriminately selected for use. The list should be used as a check to ensure that a solution has not been overlooked. Adequate technical skills should be utilized in selecting the corrective measures that will best solve the construction problem.

FINAL CONSTRUCTION REPORT - The final construction report should highlight the construction practices unique to the Idaho Batholith soils that will minimize erosion and maintain stable slopes. This information can then be shared with other Forests with similar problems.

CONSTRUCTION CERTIFICATION PROGRAM - The use of certified inspectors, Contracting Officer's Representatives, and Engineering Representatives is strongly recommended for construction work in the Idaho Batholith. Their proven expertise in certified catagories will strengthen the resource protection efforts.

Chapter 6

GUIDELINES FOR THE MAINTENANCE OF ROADS IN IDAHO BATHOLITH SOILS

INTRODUCTION - Maintenance guidelines have been developed as a means of collecting, highlighting and distributing "Best Practice"1/ methods of maintaining roads in the Idaho Batholith soils. The methods are those currently in use on one or more Batholith Forests or from studies which show the possibilities of erosion protection. The "Best Practices" as outlined are general in form, leaving the specific details of procedure, timing, frequency, and adaptation to the maintenance program up to each individual Forest. Many localized practices have proven effective in the past and should be continued. There are, however, some practices that are not effective in resource protection of soil and water which are pointed out in the guidelines.

Maintenance practices must maintain and protect the concept and integrity of the road as designed and constructed. Any contemplated change of design configuration through maintenance should be checked against the original design to avoid negating built-in resource protection measures.

FSH 7709.15 and Region 4 Supplement No. 2 give adequate guidance for maintenance operations in Idaho Batholith soils and should be used to develop a maintenance management system. Five levels of maintenance are outlined providing varying degrees of maintenance standards that can be applied to the following maintenance activity groups:

1. The Traveled Way

2. The Shoulders

3. The Drainage

4. The Roadway

5. Structures

RECURRENT MAINTENANCE - In addition to the Handbook guidance, there are areas of maintenance where special practices are being used or could be developed for the Idaho Batholith soils. The practices in use are often localized on one Forest, but they could apply to many or all areas of the Idaho Batholith. The following outline can be used as a guide to ensure the maintenance program is tailored to the erosive nature of the soils. The following outline emphasizes maintenance practices under the activity groups that can provide specific guidance in Idaho Batholith soils:

1/ "Best Practice" - Field tested and proven practices which are in use or have been in use in Idaho Batholith soils or in similar soil and terrain conditions. It combines the best technical knowledge available with the economics of application.

1. Traveled-Way Activities

a. Blading

(1) Frequencies should comply with maintenance level but they must also be responsive to the need to maintain drainage and prevent erosion damage.

(2) Inspect for blading needs after major storms.

(3) Maintain the designed inslope or outslope template. If there is a repeated occurance of template loss, the design of the road should be checked for adequacy.

(4) Don't undercut slope during blading.

(5) Prevent sidecasting of surface material during blading.

(6) Avoid excessive blading of vegetated or stabilized surfaces.

(7) Prevent surface materials from being bladed into riparian areas or stream channels.

b. Dust Abatement

(1) Select Best Product for Granitic Soils. Several products are available, but technical assistance may be needed for selection.

(a) Asphalt Products. Dust control measures using dust oils have been found to be effective on the Idaho Batholith soils if the product used contains little or no asphaltenes. Asphaletenes are the black semisolid consituent part of asphalt cement which is the base of most asphalt products. Fuel oils, including the specification item DO-4, seldom contain asphaltenes. Arcadia dust oils contain a small controlled amount of asphaltenes, usually three to five percent. Asphaltenes cause the road surface to harden or crust, which leads to extensive potholing.

(b) Nonasphalt Products. $MgCl_2$ in a brine state has had some use in granitic soils and shows promise. Water has traditionally been used but evaporates extremely fast.

(d) Pavement Structure - Aggregate. Asphalt and aggregate pavement structures solve dust problems but require more justification than dust abatement.

2. Shoulder Activities

a. Berms.

(1) Design Locations and Shapes. Berms should be maintained in the shape and at the location designed. Additional berms should not be created as part of the blading process.

(2) Problem Areas. If a berm is repeatedly breached, isolate and correct the cause as well as the berm.

b. Repair of Sloughed Shoulders

(1) Investigate and control the water problem causing the sloughing.

(2) Use a new material to repair the slough if available. Avoid using material from cuts or natural slopes where removal might cause a new stability problem.

(3) Do not sidecast waste material from the slough.

3. Drainage Activity

a. Inspect drainages and culverts in early spring prior to peak runoff from snow, after major storms, and before winter closure.

b. Clean and repair drainage systems as soon as possible to prevent compounding the problem if another storm occurs.

4. Roadway Activities

c. Seeding and Mulching. Most seeding is accomplished as part of the construction contract. There are times, however, when seeding can be beneficial during maintenance activities. Seeding and mulching should be undertaken on all bare or raw areas resulting from slips, slides, slumps, and sloughs. Seeding should include the waste and borrow areas as well as the repaired slope. Seeding should be accomplished as soon as possible after repairs and before any crusting or glazing of the soil occurs.

d. Soil Slumps - Rock Fall

(1) Cleanup of soil and rock debris should be accomplished immediately to avoid the misdirection of water.

(2) Disposal should be in designated areas that will minimize erosion. Sidecasting is generally not acceptable. Using waste to raise road grades is a practice that has shown good results.

MAJOR EMERGENCY REPAIRS - Many road failures occur that will require new design evaluation before maintenance repair. Large slope failures and drainage structure failures are the most common problems requiring technical evaluation to assure adequate and economical repair. There are, however, emergency failures which can be corrected and maintained by established best practice methods. The following outline highlights areas of major and emergency repairs where best practices can be applied or where technical assistance should be obtained:

1. Mass Soil and Rock Failures. Mass failure in the Idaho Batholith soils are numerous, but are usually limited to a few varieties such as

earth slumps, wet flows, and rock fall. Because the same types of failures usually occur, best practice methods have usually been developed on each Forest for removal and correction. However, if the failure reoccurs technical assistance should be obtained to determine the cause and specify preventive measures. Technical assistance should also be obtained if the failure is large or additional failure can occur from cleanup and removal. The two major areas of maintenance concern in mass soil and rock failures are the development of stable waste disposal sites and the determination of the cause and triggering mechanism.

a. Find Stable Disposal or Waste Areas. Often soil and rock failure results in the creation of large quantities of waste material that must be cleaned up and disposed of. The waste material which is in a highly erodible state must be disposed of in an area and in a manner that will minimize further movement of the soil and rock particles. The material should be disposed of on the flattest slopes available or the ones providing the least potential of particles entering live streams. Sidecasting of waste is a poor practice which leaves loose material on steep slopes unprotected from the forces of weather and gravity.

Slopes of the waste material in the disposal areas should be given protective treatment in the form of seeding, mulching and drainage. Compaction, stable slope ratios and benching are additional practices that can help stabilize waste areas.

b. Evaluate the Cause and Triggering Mechanism. Large failures usually require technical evaluation before cleanup operations are started to prevent further movement of the failing area. Routine cleanup generally begins at the toe and many times may trigger additional failure which could have been prevented by a different approach to removal. Redirection of surface water or interception of subsurface water may be needed as part of the corrective measures. In some cases relocation of alinement or grade may be necessary before a stable area can be assured. Adequate geotechnical skills should be employed for all geotechnical problems.

2. Structural Failures. Culverts, interceptor drains, underdrains, dips, and retaining structures often fail from inadequate design or location. When the design or location is inadequate replacement in kind will result in wasted money and time. Resource protection needs dictate careful reevaluation of design and location when repairing structural failures.

a. Drainage Structures

(1) Culverts and associated structures should be reevaluated for:

(a) Culvert size. Culverts should be designed to accommodate sediment remaining in the bottom of the culvert and still pass the design flow.

(b) Grade and alinement.

(c) Location.

(d) Protection of inlet from debris and sediment deposits.

(2) Crossroad dips provide control of road surface water and a means of getting water off the road before detrimental erosion occurs. Rototilling and shaping when the soil is wet has proven to be an effective way of constructing and maintaining dips.

(3) Subsurface drains are usually a design and construction item rather than a maintenance concern. They can, however, be used to solve some maintenance problems if the area is not too extensive. Gravel drains and pipe drains are both used with fabrics to provide an effective means of intercepting subsurface water. Horizontal drains are often equally effective in stabilizing cut slopes which are unstable because of subsurface water. Adequate geotechnical skills should be employed for all subsurface drainage installations.

c. Retaining Structures. Retaining structures can be used to solve many problems of slope failures and should be considered for any area of reoccuring slope failure. Additional geotechnical skills are usually required.

(1) Obtain Technical Assistance

(a) Forest Engineering Staff

(b) Regional Office Materials and Geotechnical Group

(c) Consulting Engineering Firms

(2) Retaining Structure Guide - Region 6

d. Protective Measures. There are many special protective measures that have proven effective in granitic soils which should be considered in major repairs. Selection of protective measures must be site specific and should utilize appropriate technical skills. Protective measures include:

(1) Gabions - Rock Baskets

(2) Energy Dissipators

(3) Trash Racks

(4) Riprap

(5) Dewatering Towers or Standpipes

(6) Sack Walls

(7) Retaining Structures

3. Fill Slope Erosion. Erosion from fill slopes has been found to be approximately 1.5 to 2 times more than the erosion from cut slopes. The erosion usually occurs in the form of sheet erosion, rill erosion or gully erosion.

a. Sheet Erosion. Sheet erosion usually occurs from rainstorms where the moving water is uniform across the slope. Vegetative covers are the best preventive measure and should be established as soon as possible. Mulching during the seeding process is essential to keep the soil and seed in place.

b. Rill Erosion. Rill erosion occurs when the water begins to concentrate and form small channels. Rills can occur from heavy or repeated rainstorms and snowmelt. Vegetation is also the best protective measure for this type of erosion; seeding, and mulching should be accomplished as soon as possible. Rilling usually occurs 8 to 10 feet below the top of the fill where the water concentration has become sufficient to erode the soil and form the small channels or rills.

c. Gully Erosion. Gully erosion is the result of heavy concentration of high velocity water. Water has concentrated sufficently to create a deep channel which usually continues to erode. The source of water must first be controlled and prevented from entering the fill area or concentrating on the fill. If possible, large rocks should be used in conjunction with granular fill material to repair the gully. Seeding and mulching should be done after repairs.

4. Other Best Practices. Putting a road to bed or the rehabilitation of the roadway after it has been removed from the transportation system should follow the best practices available to stabilize the soil. Appropriate measures could include scarification, drainage control, and vegetative cover.

Guidelines for maintenance activities have been established as a separate category from construction to provide for future inclusion of best practice methods. Best practice methods that are known have been included at this time, but they are limited because very little appears in published literature on Idaho Batholith soils. It is known, however, that many other good practices are probably currently in use by maintenance personnel in the Batholith which should be gathered, evaluated, and added to the guidelines at a future date.

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2550 Soil Interpretations

Erosion Control on Forested Lands for Interagency - Forage, Conservation, and Wildlife Handbook

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Erosion Control on Forested Lands:

Erosion control on disturbed forested lands is done to reduce sedimentation to streams which affects water quality and fishery values, as well as to protect capital investments such as roads and structures.

Erosion control on forested area involves the establishment of cover vegetation on disturbed areas associated with: Road Building - permanent access roads, Timber Harvest - skid trails, temporary roads, landings and firelines, Wildfire - burn areas and firelines, and Recreation - campsite development and maintenance, as well as ski hills and other special problem areas.

Forested lands occur over a wide range of climatic and topographic conditions. Mean annual precipitation ranges from about 16 inches to nearly 100 inches. With 40 percent at the lower elevations and 70 percent at the higher elevations coming as snow. Elevations range from 1,800 feet in northwestern Montana to over 10,000 above sea level in south central Montana. Vegetation ranges from a ponderosa pine grassland steppe to subalpine tree communities.

Due to the wide range of climatic, topographic conditions as well as complexity of the chemical and physical properties of soils, this section will deal with ideas and principles rather than specific seed mixes.

Road Building:

Cutslopes on system roads range from 3:1 on gentle ground to 1:1 and steeper on the steeper glacial tills. Fill slopes are usually 1½:1. The height of the cutslope is dependent on the steepness of the landform, road gradient, width of the road, and the depth to rock.

Seed Bed Preparation:

Where there is a tendency to dress the cuts with a slope blade which makes a very smooth and polished slope, a rough slope provides a better seedbed. Seeding a recent cutslope will take advantage of soil moisture and minimize the loss of cutslope roughness from rain storm erosion.

Timing of Seeding:

Spring is the best time for seeding, in mountainous areas, snow persistence can make this difficult. Fall seeding can have snow problems as well. The use of less than 2 inches of snow will allow contractors to seed on a skif of snow but will preclude seeding on deep snows which tend to wash the innoculant off of the legumes. The best time to seed will be when the cutslope is new and rough enough to provide a good seedbed and has moisture enough for seed germination regardless of the season.

Methods of Applying the Seed:

Dry Method - Hand cyclone seeder, air guns or blower are good inexpensive means to applying grass and legume seeds. Care needs to be taken to insure even distribution of light and heavy seeds. Applying seed with a drill is the best method, but often steep slopes preclude its use.

Hydro-mulch - Seed and fertilizer is mixed with water and sprayed on the cutslopes. Green dye or wood fiber is sometimes added as a marker to varify seeding and to its distribution. Sometimes enough wood fiber is added to the slurry to provide some mulching effect. Advantages are the seed, fertilizer, mulch and water are applied in a single operation. Disadvantages include damage to some of the seed when it goes through the pump, also the innoculent is washed off of the legume seeds. This operation requires a large crew and requires water tankers and supply trucks.

Straw Mulches - Straw mulch can be used to reduce soil loss and control erosion. Increased infiltration of water and providing a micro-site for vegetative cover are also benefits. Barley straw tends to be more weed free, but good native hay can provide a source of seed. Straw mulch can be spread by hand or mechanical blowers. Application rates of 2,000 pounds of straw per acre will cover 60 to 70 percent of the disturbed soil surface. Straw can be used to help establish cover crop on droughty sites, and to minimize sediment on critical and sensitive sites such as stream crossings. Straw mulch can be used on tall steep cutslopes for roads to help catch and hold the seed and fertilize. Asphalt emulsions and organic tackifiers as well as netting can be used to hold the straw in place. Wind, water, and gravity should be evaluated to determine the amount and method of holding the straw mulch on the ground.

Temporary Vegetative Cover Crops:

Biannuals such as winter wheat, winter rye, sweet clover or rye grass can be used as an inexpensive method to grow a temporary cover crop for erosion control. These plants provide up to 2 years of temporary cover. The permanent seed can be applied the second year and will benefit from the nurse crop as well as the mulch from the dead straw. These plants provide a range adapted to wet and dry, cool to warm sites. This method may be useful in the reclamation of borrow areas and gravel pits.

Fertilizer:

Fertilizer applied with an air gun or blower needs to be of uniform prell size to get even distribution. Otherwise the spread of the nitrogen might be in a narrower band than the phosphorous, (16-20-0) has both the nitrogen and the phosphorous in the same prell size.

Fertilizer applied with the seed:

When fertilizer and seed are applied in a blower, they should not be mixed for more than a few hours, or it could affect the germination of the seed. It is preferred not to mix the two, but to apply from separate bins or in separate operations.

Variety of Seeds:

A mixture of grasses and legumes should be blended to cover the following:

1. Sod formers and bunch grasses.
2. Moist to dry adaptations.
3. Long to short lived grasses.
4. Erosion control, wildlife benefits.
5. Germination time.

Determine the purpose and need of vegetation wanted in the future and design the seed mixes to get there. New construction is the biggest producer of sediment. Where fast establishment of cover is important, annual rye grass or small grains can be used. Legumes can provide ground cover, and food for wildlife. In addition, they fix nitrogen. Four grasses and two legumes should cover the micro-sites on difficult areas. Seed mixes should include about 100 to 150 pure line seeds per square foot. Dry areas need less and critical areas need more seed.

Maintenance of Roadside Vegetation:

Grass and legumes planted on cut and fill slopes for roads are planted on the infertile substratums. All seedings should be evaluated for seeding success during the second and third year. Bare areas can be reseeded. Areas with sufficient precipitation may benefit from supplemental fertilizer on a 3-year schedule. Legumes fix nitrogen and build organic matter to the soil. When legumes phase out of the stands they can be reestablished to help cut fertilizing costs. The Empire Variety of birdsfoot trefoil shows promise in northwestern Montana.

Seed Mixes for Erosion Control of Skid Trails, Landings, and Firelines Connected with Logging:

Erosion control devices such as water bars, and drive-through dips should be installed and road berms removed to control surface water. Temporary roads to be reused should be scarified to a depth of 4 inches to provide a seedbed for erosion control vegetation. Trails and landings to be returned to the timber base should be ripped 16 to 24 inches in depth. Seeding for erosion control should include a fast germinating cover crop such as annual rye grass or small grains. Permenant grass should include a couple of bunch grasses that are intermediate in life along with a couple of legumes for their wildlife food value and nitrogen fixing ability. The amount of seed should be about half rate that recommended for roads so as not to compete with native shrubs and trees. Plant annual rye grass at a full amount to provide quick cover on critical or sensitive areas.

Firelines and Firebreaks:

Legumes and short stemmed varieties of grasses help to control erosion and stay green throughout the burning season. Annual rye grass could provide first year protection and nurse crop for legumes if needed. Again, birdsfoot trefoil shows good promise in providing a green summer and fall firebreak in northwestern Montana.

Wildfires:

Erosion control with vegetation following wildfires require special assessment and evaluation. Small grains such as barley, oats, and winter wheat along with legumes and annual rye grass germinate quickly and are fast growing plants. Biannuals can provide cover for 2 years plus some mulching effect. Some intermediate lived grass such as slender wheat grass or timothy can provide cover until native grasses and shrubs restore the watershed. Sediment traps and straw mulching can be used on special sensitive areas where fisheries or domestic water supplies are of concern.

Recreation Areas:

Seed mixes for campsites require some of the same considerations used in establishing yards and lawns. Intensive use areas should have a mixture of sod forming grasses and legumes, while extensive use areas could have a mixture of bunch grasses and legumes. In some areas, tolerance for shade will need consideration. Once the stand is established, the grass legume composition can be adjusted with the use of fertilizer. High phosphorous fertilizers will favor legumes while high nitrogen will favor grasses.

Resting of campsites through rotation is the best way to manage heavy use areas. Short-term resting as well as alternate year use may be considered. Irrigation and fertilizer applications may be warranted on special-use areas.

Albin Martinson

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TABLE 2: SEED CHARACTERISTICS FOR GRASSES AND LEGUMES 3/ 4/
USED FOR
CONSERVATION AND FORAGE SEEDINGS

Common Name	Scientific Name	Seeds Per Pound	PLS Seeds/sq. ft	PLS Seeds/lin. ft 6 in. spacing 2/
Grasses				
Barnyard grass	Echinochloa crusgalli	115,000	2.6	1.3
Beachgrass, American	Ammophila breviliguta	-vegetative-	-vegetative	-vegetative
Beachgrass, European	Ammophila arenaria	114,000	-vegetative	-vegetative
Bentgrass, colonial	Agrostis tenuis	8,720,000	200	100
Bentgrass, creeping	Agrostis palustris	7,800,000	179	90
Bentgrass, redtop	Agrostis alba	4,990,000	115	58
Bluegrass, big	Poa ampla	917,000	21	11
Bluegrass, Canada	Poa compressa	926,000	46	23
Bluegrass, Kentucky	Poa pratensis	2,150,000	49	25
Brome, field	Bromus arvensis	280,000	6.4	3.2
Brome, smooth	Bromus inermis	125,000	2.9	1.5
Canarygrass, reed	Phalaris arundinacea	506,000	11.6	5.8
Dunegrass, American	Elymus mollis	-vegetative-	-vegetative-	-vegetative-
Fescue, annual	Festuca megalura	994,000	22.8	11.4
Fescue, creeping red	Festuca rubra	615,000	14.1	7.1
Fescue, hard	Festuca duriuscula	565,000	13.0	6.5
Fescue, sheep	Festuca ovina	680,000	15.6	7.8
Fescue, tall	Festuca arundinacea	225,000	5.2	2.6
Foxtail, creeping meadow	Alopecurus arundinacea	407.000	9.3	4.7
Foxtail, meadow	Alopecurus pratensis	500,000	11.5	5.8
Hardinggrass	Phalaris tuberosa stenoptera	347,000	8.3	4.0
Millet, Foxtail	Setaria italica	220,000	5.0	2.5
Millet, Japanese	Echinochloa crusgallis frumentacea	115,000	2.6	1.3
Millet, Proso	Panicum miliaceum	82,000	1.9	1.0
Orchardgrass	Dactylis glomerata	540,000	12.4	6.2
Ricegrass, Indian	Oryzopsis hymenoides	240,000	5.5	2.8
Ryegrass, annual	Lolium multiflorum	190,000	4.4	2.2
Ryegrass, perennial	Lolium perenne	225,000	5.2	2.6
Sudangrass	Sorghum vulgare sudanese	45,000	1.0	0.5
Timothy	Phleum pratense	1,300,000	30	15
Wheatgrass, beardless	Agropyron inerme	135,000	3.1	1.6
Wheatgrass, bluebunch	Agropyron spicatum	140,000	3.2	1.6
Wheatgrass, crested	Agropyron desertorum, A. cristatum	200,000	4.5	2.3
Wheatgrass, intermediate	Agropyron intermedium	100,000	2.3	1.2
Wheatgrass, pubescent	Agropyron trichophorum	91,000	2.1	1.1
Wheatgrass, siberian	Agropyron sibericum	250,000	5.7	2.9
Wheatgrass, streambank	Agropyron riparium	170,000	3.9	2.0
Wheatgrass, tall	Agropyron elongatum	79,000	1.8	0.9
Wheatgrass, thickspike	Agropyron dasytachyum	156,000	3.6	1.8
Wildrye, basin	Elymus cinereus	165,000	3.8	1.9
Wildrye, mammoth	Elymus giganteus	55,000	1.3	0.7

1/ @ 1 lb/ac seeding rate

2/ @ 1 lb/ac seeding rate with 6 inch drill width

3/ For woody plants, see reference list, Ag. Handbook 250.

4/ Seed data for some species contained in this guide are unavailable and not included in this table

TABLE 2: (cont.) SEED CHARACTERISTICS FOR GRASSES AND LEGUMES USED FOR CONSERVATION AND FORAGE SEEDING

Common Name	Scientific Name	Seeds per Pound	PLS Seeds sq. ft.1/	PLS Seeds/lin. ft.2/ 6 in. spacing
Cereals				
Oats	Avena sativa	16,000	0.4	0.2
Cereal rye	Secale cereale	18,200	0.4	0.2
Barley	Hordeum vulgare	13,600	0.3	0.15
Wheat	Triticum vulgare	11,400	0.3	0.15
Legumes				
Alfalfa	Medicago sativa	255,000	5.2	2.6
Beachpea, purple	Lathyrus japonicus	12,000	0.3	0.15
Clover, alsike	Trifolium hybridum	682,000	15.7	7.9
Clover, crimson	Trifolium incarnatum	179,000	4.1	2.1
Clover, red	Trifolium pratense	281,000	6.5	3.3
Clover, rose	Trifolium hirtum	140,000	3.2	1.6
Clover, strawberry	Trifolium fragiferum	288,000	6.6	3.3
Clover, subterranean	Trifolium subterranean	60,000	1.4	0.7
Clover, white	Trifolium repens	800,000	18.4	9.2
Flatpea	Lathyrus sylvestius	15,000	0.3	0.15
Peas, field	Pisum sativum arvense	18,000	0.4	0.2
Sweetclover, yellow	Melilotus officinalis	230,000	5.3	2.7
Sweetclover, white	Mililotus alba	262,000	6.0	3.0
Trefoil, birdsfoot	Lotus corniculatus	470,000	10.8	5.4
Trefoil, big	Lotus pedunculatus	1,000,000	23.0	11.5
Vetch, common	Vicia sativa	8,300	0.2	0.1
Vetch, hairy	Vicia villosa	17,000	0.4	0.2
Vetch, Hungarian	Vicia pannonica	11,000	0.3	0.15
Vetch, winter	Vicia villosa varia	11,000	0.3	0.15
Forbs				
Buckwheat	Fagopyrum esculentum F. tataricum	20,400	0.5	0.25
Burnet	Sanguisorba minor	53,000	1.2	0.6
Smartweed, nodding	Polygonum lapathifolium	189,000	4.1	2.1
Smartweed, pink ladysthumb	Polygonum persicaria	180,000	4.1	2.1

1/ @ 1 lb/ac seeding rate

2/ @ 1 lb/ac seeding rate with 6 inch drill width

POUNDS OF GRASS SEED MATERIAL REQUIRED TO YIELD ONE POUND OF PURE LIVE SEED

% PURITY*	PERCENT GERMINATION*																	
	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10
95	1.11	1.16	1.25	1.33	1.43	1.54	1.67	1.82	2.00	2.00	2.22	2.50	2.86	3.33	4.00	5.00	6.67	10.00
90	1.16	1.25	1.33	1.43	1.43	1.54	1.67	1.82	2.00	2.22	2.50	2.86	3.33	4.00	4.00	5.00	6.67	11.10
85	1.25	1.33	1.43	1.43	1.54	1.67	1.82	2.00	2.22	2.22	2.50	2.86	3.33	4.00	5.00	6.67	6.67	12.50
80	1.33	1.43	1.43	1.54	1.67	1.82	2.00	2.00	2.22	2.50	2.86	3.33	3.33	4.00	5.00	6.67	8.33	12.50
75	1.43	1.43	1.54	1.67	1.82	1.82	2.00	2.22	2.50	2.50	2.86	3.33	4.00	4.00	5.00	6.67	9.90	12.50
70	1.54	1.54	1.67	1.82	1.82	2.00	2.22	2.50	2.50	2.86	3.33	3.33	4.00	5.00	5.00	6.67	9.90	14.30
65	1.67	1.67	1.82	2.00	2.00	2.22	2.50	2.50	2.86	2.86	3.33	4.00	4.00	5.00	6.67	6.67	10.00	14.30
60	1.82	1.82	2.00	2.00	2.22	2.50	2.50	2.86	2.86	3.33	4.00	4.00	5.00	5.00	6.67	8.33	11.10	16.70
55	2.00	2.00	2.22	2.22	2.50	2.50	2.86	2.86	3.33	3.33	4.00	5.00	5.00	6.67	6.67	9.90	12.50	16.70
50	2.00	2.22	2.22	2.50	2.86	2.86	2.86	3.33	3.33	4.00	4.00	5.00	5.00	6.67	6.67	10.00	12.50	20.00
45	2.22	2.50	2.86	2.86	2.86	3.33	3.33	4.00	4.00	4.00	5.00	5.00	6.67	6.67	9.90	11.10	14.30	20.00
40	2.50	2.86	2.86	3.33	3.33	3.33	4.00	4.00	5.00	5.00	5.00	6.67	6.67	8.33	10.00	12.50	16.70	25.00
35	2.86	3.33	3.33	3.33	4.00	4.00	4.00	5.00	5.00	5.00	6.67	6.67	8.33	9.90	11.10	14.30	20.00	25.00
30	3.33	4.00	4.00	4.00	4.00	5.00	5.00	5.00	6.67	6.67	6.67	8.33	9.90	11.10	12.50	16.70	20.00	33.30
25	4.00	4.00	5.00	5.00	5.00	5.00	6.67	6.67	6.67	6.67	9.90	10.00	11.10	12.50	16.70	20.00	25.00	33.30
20	5.00	5.00	6.67	6.67	6.67	6.67	6.67	8.33	9.90	10.00	11.10	12.50	14.30	16.70	20.00	25.00	33.00	50.00
15	6.67	6.67	6.67	8.33	9.90	9.90	10.00	11.10	12.50	12.50	14.30	16.70	20.00	20.00	25.00	33.30	50.00	50.00
10	10.00	11.10	11.10	12.50	12.50	13.35	14.30	16.70	16.70	20.00	20.00	25.00	25.00	33.30	33.30	50.00	50.00	100.00

*From seed tag (FOR LEGUMES - ADD GERM AND HARD SEED TO EQUIL GERMINATION)

Apply purity and germination figures from the seed tag, and read the table in the same manner as you would a road mileage chart. Where the lines cross, the poundage shown is the approximate amount of seed MATERIAL required to yield ONE POUND OF PURE-LIVE-SEED.

EXAMPLE: Purity 35%, germination 60% comes out to 5.00 pounds of material equals one pound of pure-live-seed (PLS). Seed analysis figures seldom come out to a whole number ending in a "0" or "5" but, for use with this table, use the nearest such whole number.

EXAMPLES: 47.50 to 52.49 would read as 50%; 52.50 to 57.49 would read as 55%; etc.

VARIETY and KIND Empire Birdsfoot Trefoil

GRADE ....

LOT NO. 8

PURITY 99.57 %

GERMINATION 57 %

HARD SEED 34 %

TOTAL GERMINATION & HARD SEED 91 %

GROWN IN Wis.

DATE OF TEST 8-11-51

WEED SEEDS .00 %

INERT MATTER .03 %

OTHER CROP SEEDS .40 %

RESTRICTED WEED SEEDS 00

NO. PER POUND ....

STATE

[EXAMPLE]

MULCHES AID PLANT ESTABLISHMENT AND EROSION CONTROL ON DISTURBED SITES[1]

Burgess L. Kay[2]

ABSTRACT

Mulching increases plant establishment and and protects the disturbed site from erosive forces. Seed coverage (mulching with soil) is the single-most important practice. Mulches commonly used are organic fibers (straw, hay, wood-cellulose fibers applied by hydromulching, wood residues as wood chips and bark), fabric or mats, soil, and rock. Proper use of each mulch is discussed, including rate, method of application, and limitations.

The choice of mulch treatment or product is determined by site characteristics, availability of products, costs, and effectiveness. For the costs involved, straw and hay offer the best results in both protection and encouragement of plant growth if resulting weeds or fire hazards are not a problem. Hydraulic mulching offers a weed-free mulch of low fire hazard, with possible labor-saving in application methods, but it is seldom as effective as straw.

Chemical soil binders may be very effective for initial stabilization. These products are applied hydraulically and are usually improved by the addition of good-quality wood fiber. Plant establishment may not be improved.

Wood residues such as bark or wood chips are less effective per unit weight than straw and may easily discourage plant growth if applied at excessive rates. Fabrics and mats may be very effective if properly anchored, though problems of maintaining soil contact on rough surfaces sometimes allow excessive erosion beneath the mat. Cost may limit their use to small areas or the repair of failures.

Soil mulches are very effective, and are often inexpensive to obtain simply by leaving a rough sedged or by benching steep slopes during construction. Soil mulch may avoid premature germination caused by other mulches in the absence of adequate moisture for continued growth. Gravel mulch reduces erosion and encourages invasion of indigenous plants even on very dry sites.

Studies reported show straw to be the most cost-effective mulch practice to retain soil in artificial rainfall tests. Straw was

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[1]Paper presented at the Soil Erosion and Sedimentation Short Course, Washing State University Cooperative Extension, Olympia Washington, Feb. 22-23, 1984.

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superior to hydraulic mulches and compared favorably with the expensive fabric products. Some fabrics were inferior to straw. Jute, applied over 3,000 lbs/acre straw, was the most effective. Straw practices are discussed.

I. INTRODUCTION

Seed coverage with soil to the proper depth is essential in dry regions. Mulch, particularly hydromulching, is sometimes substituted for seed coverage when moisture is adequate. Showing the most promise in excessively dry areas are mulches applied after seed has been covered to the proper depth with soil, as with a grain drill (Springfield 1971).

The addition of mulch products to the surface of disturbed soils is the most practical way to obtain an immediate degree of protection from surface erosion and to encourage the establishment of plants for additional protection. Similar plant establishment effects on rock-free gentle slopes are created by cultivation and seed coverage, practices not possible on many erosion control sites. Even on cultivated soils the addition of surface applied mulches will sometimes offer worthwhile protection and increase the rate or amount of plant establishment.

Mulches control erosion directly by absorbing the impact of raindrops which would otherwise dislodge soil particles. They may also trap soil particles, retain water, and improve infiltration. Plant establishment is encouraged by limiting temperature extremes and retaining moisture.

The cost and effectiveness of mulching practices vary greatly. Therefore, it is important that their relative values be known. Straw was compared in this study to other commonly applied mulching practices for effectiveness in retaining soil under artificial rainfall conditions.

II. STRAW COMPARED TO OTHER ORGANIC MULCHES

Organic mulches are often an agricultural crop residue or industrial by-product. The price usually reflects transport and handling cost more than intrinsic value of the product.

Most organic mulches require additional nitrogen to compensate for the tie-up of nitrogen in the decomposition process.

Effectiveness is roughly related to the size and shape of the mulch particles. Long narrow particles are superior to finely ground products. Following is a discussion of recent tests comparing organic mulches commonly used.

Surface applied mulches were tested on 2 ft x 4 ft soil surfaces inclined at 5:1 and/or 2:1 (horizontal to vertical measurement). Artificial rainfall of 0.12 inch diameter drops falling 15 ft at the total amount of 6 inches/hr was applied to duplicate samples of the surfaces for periods of two to six hours. The boxes containing the soil were designed to allow rapid drainage if water moved through the 6 inch

profile. Soil washed from the slope surface was collected, dried, and weighed.

Mulch treatments include hydraulically applied virgin wood fiber mulch (Silvafiber[R]) at rates of 1,500 and 3,000 lb/acre; barley straw at rates of 1,000, 2,000, 3,000 lbs (tacked to the surface with asphalt emulsion at 200 gpa) and 8,000 lb punched into the soil with a shovel. Fabrics stapled to the soil were jute, excelsior, and paper (Hold/-Gro[R]); and jute stapled over 3,000 lb of straw. These were compared to no surface protection. The percent of the surface covered with the various straw and fabric treatments was measured with a point frame (100 points/replication), and are listed with weight/acre of various products (Table 1).

Table 1. Percent of surface covered and weight of mulch product.

	lb/acre	Percent cover
Hydraulic mulch	1,500	95
Hydraulic mulch	3,000	100
Straw	1,000	48
Straw	2,000	66
Straw	3,000	78
Straw	8,000	86
Jute	5,050	58
Excelsior	3,300	72
Hold/Gro	850	95
Jute + straw	8,050	96

The eight "soils" used in the tests were often subsoils or mixtures of profiles taken from construction sites. The Arnold fine sand was from a road cut near Prunedale, decomposed granite a road cut near Carson Pass, Cieneba gravelly sandy loam from a motorcycle park near Hollister, Dibble sandy clay loam from a brush area in Yolo Co., Los Osos loam from a construction site near Hercules, Yolo loam from Davis farmland, Auburn-Sobrante loam from the surface in the foothills of the

Sacramento Valley near Browns Valley, and Altamont clay loam from a motorcycle park near Livermore. Soils were not compacted into the boxes other than by repeated waterings. Bulk density was measured periodically, at or near field capacity to be sure all treatments were comparable. Texture and particle size are shown in table 2.

Table 2. Texture, series name, and particle size of soils tested (percent).

Texture	Name	Clay	Silt	Sand	Gravel
Uncemented fine sand	Arnold	2	3	95	0
Very gravelly coarse sand	Decomposed granite	3	4	41	52
Gravelly sandy loam	Cieneba	9	9	49	33
Sandy clay loam	Dibble	21	18	61	0
Loam	Los Osos	17	48	35	0
Loam	Yolo	22	45	33	0
Loam	Auburn-Sobrante	21	43	36	0
Clay loam	Altamont	29	45	26	0

RESULTS

Erodability of Soils

The unprotected soil surfaces varied considerably in the amount of soil lost (Figure 1). Loss was greater from all soil types when inclined at 2:1 than at 5:1. Least erodable were the soils containing gravel and the soil with the highest clay content. Much of the water flows through the gravelly soil draining out of the bottom of the boxes. Also the surface gravel particles absorb much of the energy from the water drops without being dislodged. By contrast the montmorillonite clay particles of the Altamont soil are firmly bonded together, and while they don't allow water to readily drain through, they are able to withstand considerable impact energy of the drop sizes used here.

Most erodable were the soils with high percentages of fine sand and silt. The Arnold fine sand allowed some infiltration but soon saturated and liquified. Steepness of the slope then became important in determining how fast the liquified soil flowed from the slope. Also highly erodable are the loams which are particularly important because they commonly occur on coastal sub-division sites.

The hydraulic mulch rates were compared to 3,000 lbs of straw on seven soils at both 5:1 and 2:1. The effect on soil loss is shown in figure 2.

Straw provided much greater protection than wood fiber on all soils, but was most dramatic on DG, uncemented fine sand, and clay. The protection was so complete that the regular two-hour test was increased to as much as six hours. The excellent performance of straw on uncement-

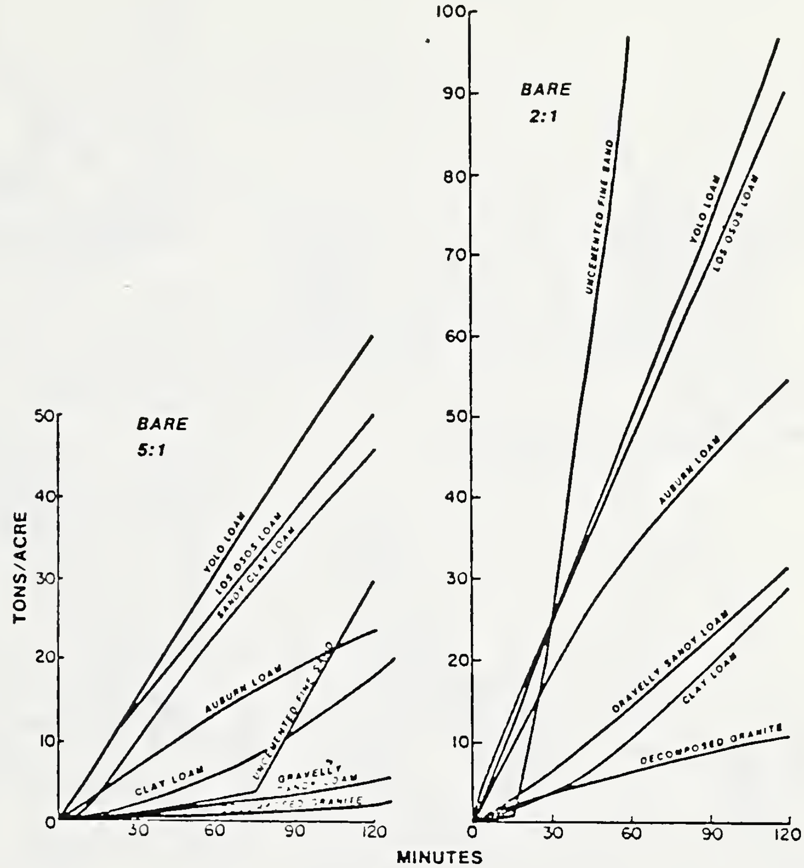

Figure 1. Erosion rates (tons/acre) of unprotected soil surfaces inclined at 5:1 and 2:1.

Straw vs. Hydraulic Mulch

ed fine sand was particularly impressive because this soil liquifies and flows if not protected by a mulch. Wood fiber, though inferior to straw, offered some protection. Increasing the commonly used rate of 1,500 lb to 3,000 lb provided additional protection only on a fine sand at 5:1 and DG at 2:1.

Straw increased the infiltration rate of water on both DG and uncemented fine sand compared to bare soil as indicated by reduced volume of runoff. Wood fiber, by contrast, increased the volume of runoff on both soils.

Loam and sandy clay loam soils were much more erodable than either coarse textured or clay soils but the same mulch relationship existed. Straw was superior to hydraulic mulch (1,500 lb) on both slopes. Increasing the rate of hydraulic mulch to 3,000 lbs increased its

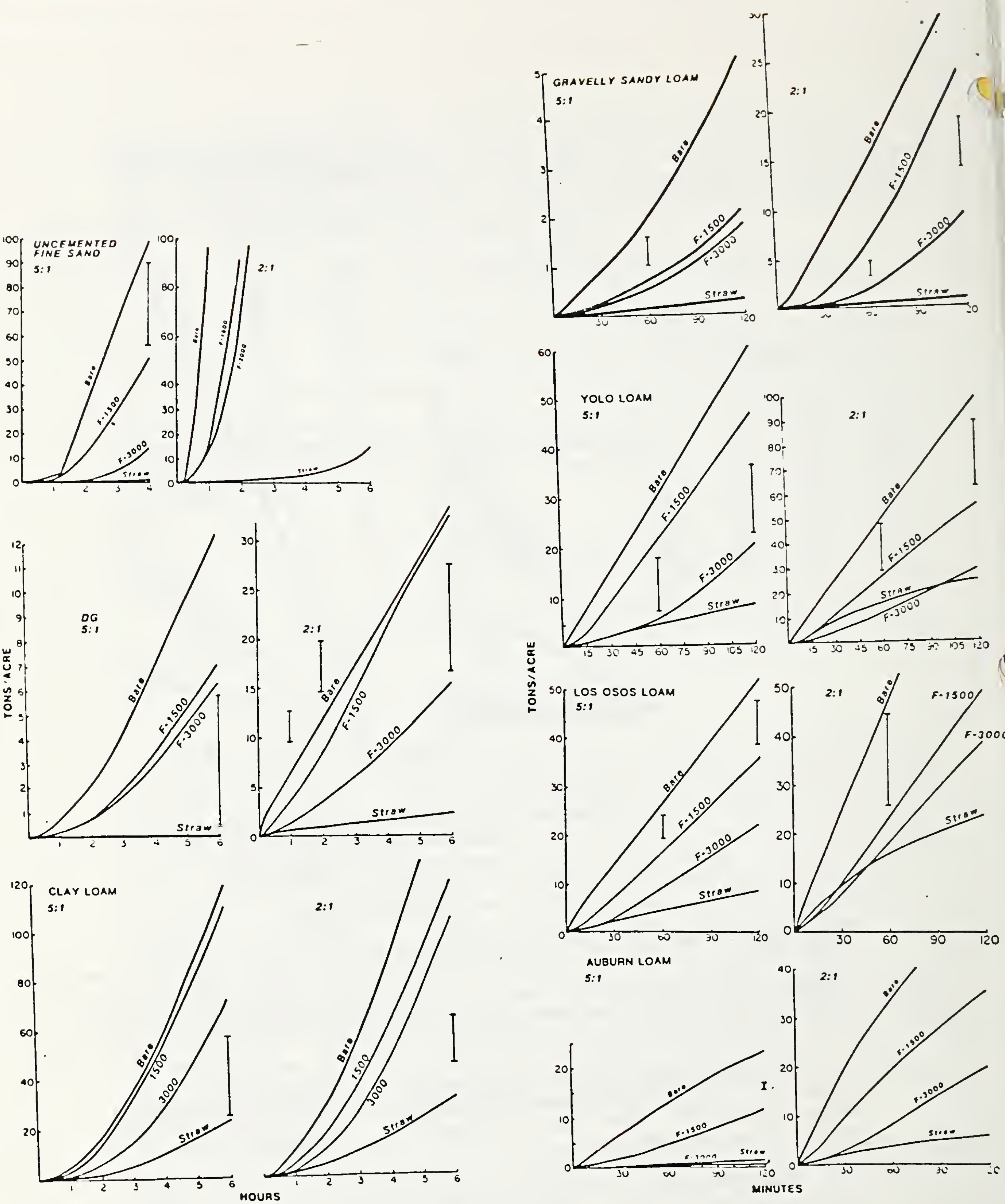

Figure 2. Effects of mulch treatments on soil loss (hydraulically applied wood fiber at 1500 and 3000 lbs/acre and straw at 3000 lbs/acre compared to bare soil) on seven soils at 5:1 and 2:1 slopes. Vertical insets indicate size of significant differences at .05 level.

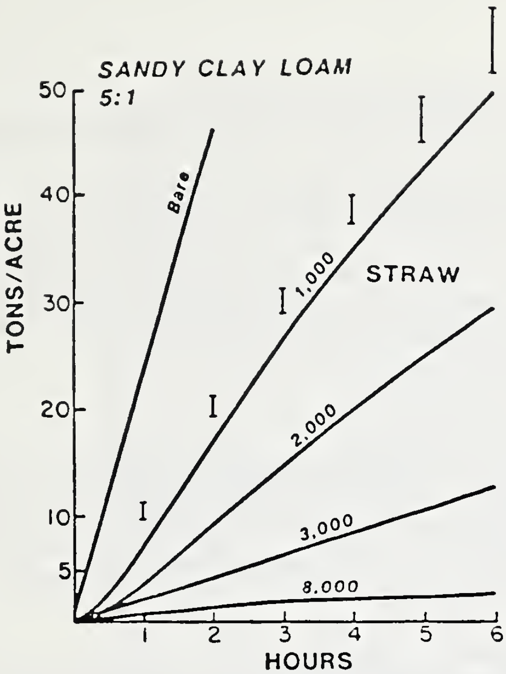

Figure 3. Effect of straw mulch rates on soil loss on 5:1 slopes, sandy clay loam soil. Vertical insets indicate a significant difference at .05 level.

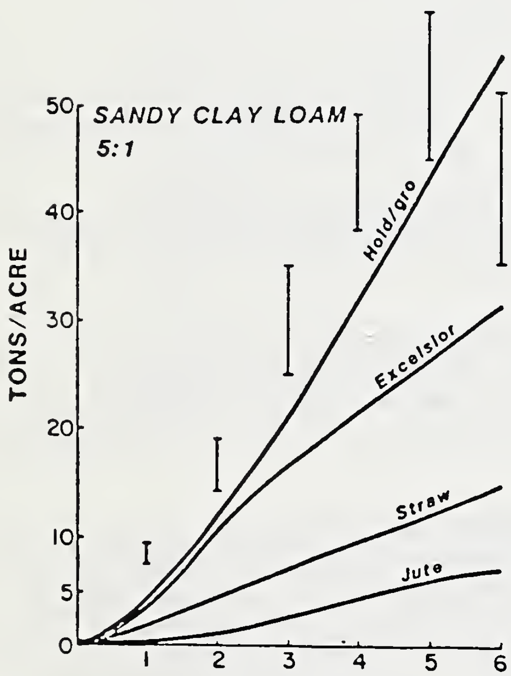

Figure 4. Effect of erosion control fabrics and straw on soil loss on 5:1 slopes, sandy clay loam soil. Vertical insets indicate significant difference at .05 level.

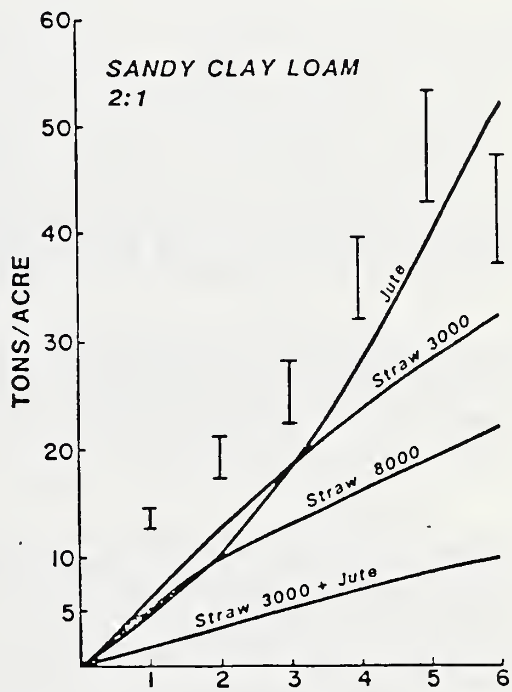

Figure 5. Effect of erosion fabrics or straw on soil loss on 2:1 slopes, sandy clay loam soil. Vertical insets indicate significant difference at .05 level.

effectiveness. On Yolo loam at 2:1, 3000 lbs of fiber compared favorably to straw.

Auburn loam was less erodable than other loams. The 3,000 lb of hydraulic mulch was superior to the 1,500 lb rate at 5:1 and comparable to 3,000 lb of straw. However, when the slope was increased to 2:1 straw was much better than the high rate of hydraulic mulch which was still better than the low rate of hydraulic mulch.

Rates of Straw

Because straw is so effective it is important to choose the correct rate. In addition to the 3,000 lb tested above, lesser rates of 1,000 and 2,000 lb were compared on a sandy clay loam soil at 5:1. Also tested was straw punched into the slope at 8,000 lb/acre, a commonly used fill-slope treatment in California.

All treatments were very successful, allowing us to extend the test to six hours, even though this is a very erodable soil. Each increase in the amount of straw reduced the amount of soil lost (Figure 3).

Straw vs. Fabrics

The most commonly available fabrics are jute, excelsior, and paper strip-synthetic yarn product (Hold/Gro). These were compared to straw at 3,000 lb/acre, also on a sandy clay loam at 5:1 for six hours.

Straw and jute were the most effective treatments and not significantly different from each other. Excelsior was less effective but better than the paper product (Figure 4).

Jute is sometimes used on top of straw for added effectiveness. This treatment was therefore compared to the other most effective treatments--straw punched at 8,000 lbs, straw tacked at 3,000 lbs, and jute alone. Because we expected these treatments to be very effective the slope was increased to 2:1.

Jute plus straw was the most effective and better than 8,000 lb of straw which was better than 3,000 lb of straw (Figure 5). Although jute alone was very effective at 5:1 in the previous test, it grew progressively worse during this test. It was as effective as 8,000 lb of straw for over two hours, but then performance deteriorated as soil washed from beneath the fabric.

DISCUSSION OF RESULTS

These tests illustrate the importance of soil texture in erodability and the large differences in the effectiveness of mulch treatments for retaining soil. Also different are the costs of these treatments. Straw, though consistently the most effective treatment, is not expensive. At the rate of 3,000 lb/acre it is comparable in cost to hydraulic mulches at 1500 lb/acre and only 25% of the cost of installed fabrics (Kay, 1978).

Straw has been largely replaced in California by the currently popular hydroseeding techniques (hydraulic slurry applications of seed, fertilizer, mulch fibers, and possibly chemicals). Field and laboratory tests, such as reported here, consistently illustrate that straw is superior not only to retain soil but also to increase the establishment of plants.

The mulch effect of straw can be expected to increase plant numbers. Meyer et al. (1971) obtained fescue-bluegrass establishment of 3, 28, and 42% with respective surface straw mulch treatments of 0, 1, and 2 tons/acre. Straw has been shown by the author to increase plant establishment in decomposed granite. Seeding the annual grass Blando brome (<u>Bromus mollis</u>) resulted in 7, 6, 26, 35, and 131 seedlings/ft^2 respectively on the untreated, fiber mulch at 1,000, 2,000, and 3,000 lb/acre, and straw at 2,000 lb/acre on a 2:1 slope. On 1.5:1 the number of plants were 1, 13, 29, 35, and 131, and at 1:1 slopes 0, 10, 27, 20, and 155. Seed coverage with soil produces superior stands when compared to hydraulic applications (Kay, 1979, Packer and Aldon, 1978). Fertilizer or legume seeding must be applied to compensate for the nitrogen tied up in decomposing the straw.

Size of mulch particles is important because of the mass required to absorb the energy in the water drops. Even though the hydraulic mulches provided the most complete ground cover (Table 1) they were too small to be effective.

Straw length may be important, particularly if it is to be punched into the soil, in which case longer straw is desirable. New agricultural practices are resulting in shorter lengths. The flails used in straw blowers will further shorten straw. The barley straw used in these tests was about 10 inches, ranging from 1-23 inches.

Soil contact is particularly a problem with the fabrics. They frequently allow erosion to occur from beneath them. A layer of straw under the fabric will improve this contact (Figure 5).

III. DISCUSSION OF STRAW PRACTICES

Cereals are a major crop in dry regions of the United States, and straw left on the site of production is often considered a liability because its decomposition ties up nitrogen needed for the next crop. Straw availability should be increased by current restrictions on removing this crop residue by burning in place. Clean grain straw, free of noxious weeds, is preferred for mulching. The straw can be expected to contain 0.5 to 5.0% cereal seed by weight, which may result in considerable plant cover in the first year. This provides additional erosion protection but may also be prohibitively competitive with the planted erosion-control or beautification mixture. Rice straw is sometimes used because neither the rice nor associated weeds can be expected to grow on most unirrigated disturbed lands. In areas where cereal crops are not common, hay is sometimes used but is normally more expensive than straw. Wild-grass hay may be a valuable source of native plant material if cut when the seeds are ripe but not shattered.

Straw can be applied with specially designed straw blowers or spread by hand. Commercial mulch spreaders or straw blowers advertise a capability of up to 15 US tons/hour and distances to 85 ft. The length of the applied straw may be important and can be controlled in most blowers by adjusting or removing the flail chains. Baled straw may also be relatively long or short, depending on agricultural practices. Straw to be crimped or punched should be relatively long to be incorporated into the soil effectively and still leave tufts or whisker dams. Rice straw is wiry, dirty, does not shatter readily, and consequently does not blow as well as straw of wheat, barley, or oats. It may come out of the blower in 'bird nests'. Blown straw (other than rice) lies down in closer contact with the soil than hand-spread straw and is anchored more successfully with a tackifier (substance sprayed on straw to hold it in place). Wind is a serious limiting factor in applying straw, though it can be an asset in making applications downwind. Dust, a problem in urban areas, can be overcome by injecting water into the airstream used to blow the straw.

The amount of straw to be used will depend on the erodability of the site (soil type, rainfall, length and steepness of slope), kind of straw (Grib, 1967), and whether plant growth is to be encouraged. Increasing rates of straw give increasing protection. Meyer et al. (1970) show that as little as 1,000 lb/acre reduced soil losses by two-thirds, while 4 tons/acre reduced losses by 95%. Straw to be crimped is commonly used at 2 tons/acre, while straw punched into fill slopes in California is at 4 US tons/acre in a split application and rolling operation (2 tons/acre each). Straw to be held down with a net should be limited to 1.5-2 tons/acre if plant growth is important. Too much straw may smother seedlings by intercepting all light or forming a physical barrier. Also, some grass straw (notably annual ryegrass, Lolium multiflorum) may contain inhibitors that have a toxic effect if used in excess. A good rule of thumb is that some soil should be visible if plant growth is wanted. Higher rates of straw may of course still satisfy these requirements if the straws are vertically oriented (like tufts) by crimping or punching. Excessive straw on the surface may be a fire hazard.

Straw or hay usually need to be held in place until growth starts. The problem is wind, not water. Water puddles the soil around the straw and helps hold it in place. Also, wet straw "mats down" and is not easily moved. If the straw covered area can be irrigated, or if rainfall is imminent, it will not be necessary to anchor the straw.

Common methods of holding straw in place are crimping, disking, or rolling into the soil; covering with a net or wire; or spraying with a chemical tackifier. Swanson et al. (1967) found similar protection from prairie hay applied as a loose mulch or anchored with a disk packer (crimper).

Crimping is accomplished with commercial machines which utilize blunt notched disks which are forced into the soil by a weighted tractor-drawn carriage. They will not penetrate hard soils and cannot be pulled on steep slopes.

Rolling or "punching" is done with a specifically designed roller. Not satisfactory for incorporating straw is a sheepsfoot roller, commonly used in soil compaction. Specifications of the California Department of Transportation contain the following provisions (State of Calif., 1975): "Roller shall be equipped with straight studs, made of approximately 7/8 inch steel plate, placed approximately 8 inches apart, and staggered. The studs shall not be less than 6 inches long nor more than 6 inches wide and shall be rounded to prevent withdrawing the straw from the soil. The roller shall be of such weight as to incorporate the straw sufficiently into the soil so that the straw will not support combustion, and will have a uniform surface."

The roller may be tractor-drawn on flat areas or gentle slopes, whereas on steeper slopes the roller may be lowered by gravity and raised by a winch in yo-yo fashion, commonly from a flat-bed truck. Requirements are soil soft enough for the roller teeth to penetrate, and access to the top of the slope. This is a common treatment on highway fill slopes in California. It can be used on much steeper slopes than a crimper. Punched straw may not be as effective as contour crimped straw, because of the staggered arrangement of tucked straw instead of the "whisker dams" made by crimping (Barnett et al., 1967).

A variety of nets have been used to hold straw in place: twisted-woven kraft paper, plastic fabric, poultry netting, concrete reinforcing wire, and even jute. Price and the length of service required should determine the product used. These should be anchored at enough points to prevent the net from whipping in the wind, which rearranges the straw.

Perhaps the most common method of holding straw, particularly in the eastern U.S., is the use of a tackifier. This method may be used on relatively steep slopes which have limited access and soil too hard for crimping or punching. Asphalt emulsion, the tackifier used most commonly, is applied at 200-500 gal/acre--either over the top of the straw or applied simultaneously with the straw blowing operation. Recent tests (Kay, 1978) have shown that 600 gal is superior to 400 gal. and that 200 gal/acre is not satisfactory. Wood fiber, or new products used in combination with wood fiber, have been demonstrated to be equally effective, similar in cost, and environmentally more acceptable (Table 3). Though wood fiber alone is effective as a short-term tackifier, glue must be added to give protection beyond a few weeks. Terratack I is a gum derived from guar (Cyamopsis Tetragonoloba). Ecology Controls M Binder is a gum from plantain (Plantago insularis). The remaining products are emulsions used in making adhesives, paints, and other products. Increasing the rate/acre of any of the materials will increase their effectiveness.

IV. DISCUSSION OF HYDRAULIC MULCHING

Hydraulic mulching, or hydromulching, is a mulch applied in a water slurry. This same slurry may also contain seed, fertilizer, erosion-control compounds, growth regulators, soil amendments, etc., and is increasingly popular because of low labor requirements. Mulches must have a particle size small enough for ready pumping through 0.5-inch nozzles, and must not be too buoyant to remain in suspension with moderate agitation.

Table 3.--Effects of tackifier products on wind stability of barley straw broadcast at 2,000 lb/acre.

Product	Chemical	Fiber lb	Water gal	Wind speed (mph at which 50% of straw was blown away)
None				9
SS-1 asphalt	200 gal			40
SS-1 asphalt	400 gal			80
SS-1 asphalt	600 gal			84
Fiber only		484		47
Fiber only		736		84
Terratack I	45 gal	150	750	68
Ecology Control M-Binder	100 lb	150	700	84
Styrene butadiene copolymer emulsion (SBR)	60 gal	75	400	84
Polyvinyl acetate (PVA)	100 gal	250	1000	54
Copolymer of methacrylates & acrylates	100 gal	250	1000	76

The standard mulch in the hydraulic seeding industry has long been virgin wood fibers of alder, aspens, and hemlock, which have good stability and water holding capacity. Tests have shown that corrugated paper (Kraft) will also make a satisfactory mulch. Recycled paper make an excellent mulch although it was earlier given a bad name because of the very poor quality of paper products marketed in California under the names Tinex and Necco Fiber (no longer available). Also unsatisfactory in earlier tests were ground barley straw, washed dairy waste, rice hylls, and alfalfa pellets. A satisfactory mulch can also be made from grass or cereal straw by defibrating. The presteamed chopped straw is passed through close-tolerance discs and dried. A commerical product is now being marketed. I suggest that it could be improved by more complete defibrating and drying.

The tests reported here were conducted on both commercial and experimental products for water-holding capacity (WHC) and stability (Table 5). WHC was tested by the methods of both the U.S. Forest Service and the California Department of Transportation, which give the weight ratio of water to dry mulch (Table 5). Both are arbitrary laboratory tests involving much less aggitation and soaking time than field use and may or may not relate to the WHC under field conditions. Stability was measured by applying the mulches at the rate of 2,500 lb/acre to soil surfaces with a small hydromulcher, inclining the surfaces at 45° after drying thoroughly; and subjecting them to artificial rainfall of 6 inches/hr with 3 mm drops. The samples used in this test may or may not be representative of the day-to-day production of the product; they are single samples as submitted by the company.

Paper can be used to manufacture an excellent hydromulch. Particularly effective are products containing newsprint, either alone or in combination with other fibers (Figure 6). The stability of virgin

Table 5 Results of tests with hydromulch products.

Commercial name	Raw material	% moisture[1]	Water-holding capacity (WHC) Cal-Trans[2]	Water-holding capacity (WHC) USFS[3]	Stability[4]	Comments
1. Conwed hydromulch - Minnesota	Virgin aspen wood fiber	--	14.7	13.9	Good	Long-time standard in the industry.
2. Conwed hydromulch 2000 Minnesota	Virgin aspen with organic tackifier	--	14.2	--	Good	Pumps easier. No improvement in stability or WHC.
3. Silva-Fiber - Washington	Virgin alder wood fiber	15.6	14.7	15.4	Good	Long-time standard in the industry.
4. Grass Mulch Oregon	Defibrated ryegrass straw	23.0	10.0	6.2	Fair	High moisture. Not all defibrated. WHC low.
6. Jacklin Mulch - Washington	Grass seed screening		4.5		Very poor	WHC low, no fiber.
7. Fibron - Oregon	Chipstock cardboard	7.4	14.5	13.7	Good	No longer available.
8. Agrifiber - California	Corrugated paper	7.1	15.8	17.1	Good	High WHC
9. Cal-Fiber - California	Selected newsprint	12.4	14.6	13.5	Excellent	
10. Cal-fiber - California	Selected newsprint	5.4	13.5	11.8	Excellent	
11. Astromulch - California	50:50 newsprint and corrugated	8.8	13.9	10.8	Excellent	
12. Fibercel - Texas	Unknown	17.7	10.2	9.6	Poor	Moisture high and WHC marginal.
13. Necco - California	Waste paper	7.6	11.6	9.8	Very poor	No longer available.
14. Finex - California	Waste paper	20-70	7.7	--	Very poor	No longer available.
15. Spra-Mulch - Illinois	Magazines	7.4	7.7	4.0	Very poor	WHC low, ash high.
16. Verdyol - Switzerland	Raw cotton and cellulose pulp	--	11.1	7.6	Fair-good	WHC below USFS specifications.
17. Experimental	50/50 news & Silva-Fiber	14.0	14.9	15.4	Excellent	
18. Experimental	50/50 corrug & Silva-Fbr.	11.4	16.5	17.8	Good	

[1] Moisture was determined by oven-drying. If sample was small or a long time in storage, no value is given.

[2] Water-holding capacity for hydromulch. 1976. Thomas Hoover. Calif. DOT ICA-DOT-TL-2167-1-76-36.

[3] Method for determining water holding capacity of hydromulch. 1976. Vance C. Setterholm. U.S.F.S., Region Two.

[4] Observed on decomposed granite surface inclined at 1:1 and subjected to the impact of 3-mm water drops at 6 in/in.

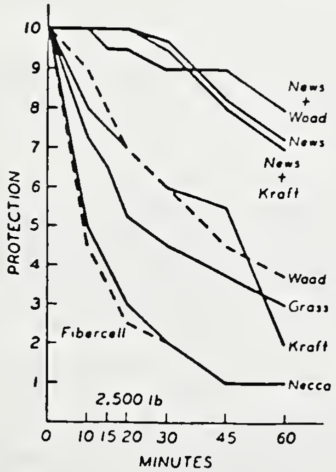

Figure 6 Effect of simulated rainfall on surface protection of hydraulic mulches applied at 2,500 lb/acre. Newsprint alone or in combination with wood or kraft fibers gives the best protection.

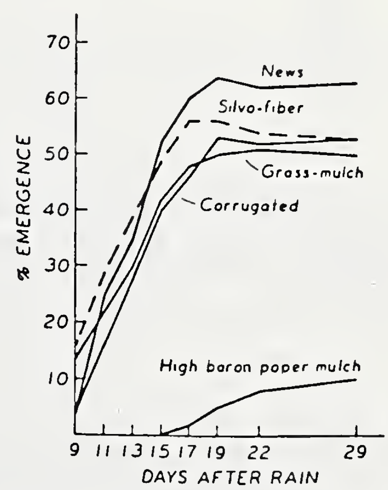

Figure 7 Percent emergence of Blando brome under natural rainfall conditions. Mulches applied at 2,000 lb/acre over top of seed. Emergence is similar with all products except one containing boron at 6,000 ppm.

To simplify information, trade names of products have been used. No endorsement of named products is intended, nor is criticism implied of similar products which are not mentioned.

wood fiber or corrugated paper fiber is improved if combined with equal parts of newsprint fiber. All form a papier-mache type of surface when dried.

The grade of paper used appears to be critical. Newsprint can be very good. The material received from Cal-Fiber was made of newsprint from which had been removed other grades of "slick" paper (such as the "sunday supplement", magazines and advertisements). Slick papers contain clays, which appear to harm both WHC and stability. An example of mulch made from magazines is Spra-Mulch (not to be confused with a product by the same name in the West which is made of virgin wood fiber). Magazines result in a product of low WHC, high ash content, and very poor stability. The ash content of Spra-Mulch was 23.6% which exceeds the USFS limit of 7%. Some paper products may have performed poorly in the past because little or no attention was given to paper quality.

WHC of paper mulches is determined in part by the particle size of the paper product (screen size used in the hammermilling process which is used to grind the paper) if measured by the arbitrary tests cited in Table 4. The large sizes would probably show increased WHC if aggitated longer. The WHC of newsprint and corrugated paper ground with various screen sizes is shown in Table 2.

Table 4. Effect of hammermill screen size on WHC of fiber products made from newsprint or corrugated paper. WHC was measured by the USFS method.

Screen size-inches	Water-holding Capacity	
	Newsprint	Corrugated
6/16	16.4	--
3/8	12.7	--
7/16	11.4	15.1
3/4	6.8	7.6
2.0	5.3	3.7

Stability and WHC appear to be correlated. Products with stability ratings of good or excellent all have high WHC (above 12--average of two methods), while products with poor or very poor stability have the lowest WHC. US Forest Service specifications for Region Two require a WHC of not less than 9 to 1 which would eliminate some, but not all of the products that rated fair to very poor in this test. An exception is an experimental mulch made from paper cups which had a low WHC because of the wax, but good stability. The wax cups may have been more thoroughly wetted after passing through the hydromulcher. Necco fiber was not eliminated by the 9 to 1 specification.

Drying after application is important to obtaining maximum stability of all mulches. None are very stable immediately after application. In the wet condition paper is about as effective as wood.

Paper, wet or dry, appears to allow more water to enter the soil (better infiltration), while wood fiber sheds a portion of the water.

A potential problem with hydromulches is the threat of boron contamination. Some manufacturers of these mulches (wood and paper) also market insulation products, which are made in a like manner but with fire-retardant materials added. Commonly used for this purpose is boric acid or borate, which not only are fire retardants but also are very effective soil sterilants and must therefore be excluded from mulching products. This is a problem in manufacturing, and is not inherent in the paper or wood used as raw materials. Figure 7 shows the problem encountered with the emergence of the annual grass blando brome (*Bromus mollis*) with a sample of 50-50 news/corrugated mix containing 6,000 ppm boron[3] compared with other mulches that show no germination or growth problems. The company now recognizes the problem and thoroughly cleans the grinding machinery before manufacturing mulch.

Other problems with paper mulches that the industry must address may be equally easy to overcome. We are spoiled by the excellent packaging, wettability, and dye of wood fibers. Some paper products, being insufficiently compressed, result in excessive bag handling (25-30 lb instead of 50). Some do not contain a dye, while at least one offers the option of a dye or a lower price without a dye. Some paper products tend to wet more slowly than wood, but should not be a problem if added to a machine half full of water or while filling as suggested by most machine manufacturers. Other paper products have added a wetting agent to speed wetting.

A problem we have yet to solve is how to write specifications which will exclude products of the poor quality experienced in the past. The best specifications so far are those of Region Two of the U.S. Forest Service which in part require the use of No. 1 mixed paper or corrugated, maximum moisture of 15%, WHC 9 to 1 or greater, and inorganic or ash content less than 7%.

Commercial fibers are usually dyed with a fugitative green dye which lasts only a few hours or days. This visual aid assists in obtaining an even distribution on the slope.

Rates of hydromulch vary from 500 to 3,000 lb/acre. The rate of 500 lb/1,500 gal water is suggested as necessary to disperse seeds evenly in the slurry, and to protect seed in passing through the centrifugal pumps commonly used in hydraulic seeders. This would cover one to three acres, with best coverage on one acre and possible

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[3]Boron determinations were made as described in the Determination of Boron with Carmine by John T. Hatcher and L. V. Wilcox which appears in Methods of Analysis for Soil, Plants, and Water; Homer D. Chapman and Parker F. Pratt; Univ. of Calif. Division of Agricultural Sciences, Aug. 1961. Decolorizing carbon was used to remove the ink or dye before making the determination.

distribution problems if used on three acres. A minimum of 1,000 lb/acre is necessary to hold the seed on a slope. An inconsistent "mulch effect" has been observed with less than 1,500 lb/acre. Currier (1970) expressed some concern that "60-70% of the seed hangs up in the mulch and has little or no chance to get its primary roots into mineral soil." Studies with wood fiber showed that under conditions of adequate moisture, small grass seeds such as Durar hard fescue could emerge through as much as 9,000 lb and readily emerge from between two 1,000-lb layers. Placing the seed on top of 2,000 lb speeded emergence and total germination of orchardgrass, and did not reduce emergence of any of the other five species tested.

Under conditions of limited moisture, created by applying the mulch over seed broadcast on greenhouse flats filled with various problem soils, inclining the flats at slopes of 1:1, 1.5:1, or 2:1 (horizontal to vertical measurement) and exposing them to natural rainfall yielded the data on page 9. On the steepest slopes (1:1 and 1.5:1), 1,000-2,000 lb of fiber was necessary to hold the seed in place. Without that amount, no seedlings were established. On the flatter 2:1 slope, the 1,000-lb rate did not improve the stand whereas 2,000 lb did. Increasing the rate to 3,000 lb increased the number of seedlings on the most severe test with either decomposed granite or fine sand. In recent tests by the author near Lake Tahoe, California, 4,500 lb resulted in good grass stands, while 3,000 lb produced only a few seedlings, because of excessive frost heaving.

Wood fiber is an essential addition to most hydraulically applied chemicals, including straw tackifiers. Many soil-binding chemicals will not hold seed, fertilizer, or straw to a slope unless wood fiber is included.

C. Wood Residues

Wood residues (woodchips and bark) can be used effectively if locally available as a waste from the forest-products industry or chipped on the site during land clearance. Smaller wood-residue particles, such as shavings or sawdust, would be subject to wind loss. Woodchips and bark can be applied with a conventional straw-blower to a distance of 18 m (Emanuel 1971). The rate must be twice that of straw to obtain the same soil protection (Meyer et al., 1972) or even as much as 6 times the straw rate (Swanson et al. 1965). Observations in California indicate that uneven distribution often results in poor or no plant establishment in the heavier (100% ground cover) applications.

D. Fabric or Mats

Fabric or mats, including jute, exelsior, and woven paper or plastic fibers, are provided in rolls to be fastened to the soil with wire staples. Fiberglass roving (which is blown on with compressed air and tacked with asphalt and emulsion) is also available as a nonbiodegradable substitute. Use of these products is limited by their cost and effectiveness. The rolls require high labor inputs for installation, cost at least four times as much as tacked straw, and are not adapted to fitting to rough surfaces or rocky areas. Erosion from

beneath these products is common because they do not have intimate contact with the soil. They must be heavy enough or anchored in enough spots to prevent wind whipping. Several reports indicate they are not as effective as straw (Springfield, 1971). They have the advantage of being weed-free but may be unsightly, a fire hazard, or (in some cases>) nonbiodegradable or too rapidly biodegradable to be effective. Dudeck et al. (1970) found excelsior mat or jute to yield the best seedling grass of eleven mulch treatments tested. Swanson et al. (1967) found jute, excelsior, and prairie hay or fiberglass anchored with asphalt emulsion to be the best of all treatments.

Mats would be used only on small areas, such as to repair failures of other treatments, where time and cost factors are of secondary importance. They should be maintained, repairing tears, etc., before wind or water can cause extensive damage.

V. CHEMICALS

Chemicals to be used as a mulch, humectant (a substance that absorbs or helps another substance retain moisture), or soil binder are usually applied in a water carrier or as part of a hydraulic seeding slurry. They are expensive and very specialized, and must be used correctly for maximum effectiveness. They are not substitutes for sound agricultural or engineering practices, regardless of glowing advertisements. Products are discussed here as either fiber tackifiers (including humectants) to be used as part of a seeding, or plastic emulsions which may be used with a seeding or alone as a soil binder.

A. Fiber Tackifiers

Fiber tackifiers are generally advertised to hold fiber in place, promote germination, hold moisture, and retard erosion. Most sales literature acknowledge that fiber should be used with the product. Within this group we have tested Ecology Controls M-Binder, Kelgum, Terratack I, Styrene butadiene, Super Slurper, and PVA.

Although virgin wood fibers as a hydraulic mulch adhere well to slopes without the addition of glues or tackifiers, interest continues in products which would improve their resistance to wind or rain. Of the variety of products previously tested, only a few improved the fiber characteristics, and then only slightly or inconsistently. Most products do make the slurry easier to pump, perhaps allowing the addition of more fiber/load.

Most existing products are sensitive to fertilizer. Adding 16-20-0 ammonium phosphate-sulfate at 500 lb/acre to 1,500 lb of wood fiber greatly reduced the effectiveness of Terratack III (an alginase), Ecology Controls M Binder (husk of Plantago insularis), PVA (polyvinyl acetate homopolymers or vinyl acrylic copolymers), Super Slurper, and SBR (styrene butadiene). These and all following tests involved applying treatments to greenhouse flats, inclining the flats at 1:1 after curing, and exposing them to artificial rainfall of 3-mm drops at 6 inches/hour.

An improved SBR (styrene butadine) product is sold for erosion

control. The earlier SBR products differ considerably in pH (acidity) and can therefore be expected to perform quite differently. The product tested in the most recent studies is XFS 4163-L Dow mulch binder, a liquid which utilizes a dry powder modifying agent (methyl cellulose).

Applications of Dow SBR without fertilizer in a slurry with 1,500 lb/acre fiber have shown their superiority to other products. The Dow SBR is made only slightly less effective by fertilizer. Previously tested was another SBR product which was seriously affected by fertilizer in that rubber balls were formed when fertilizer was added.

Improved Application Methods

Tests have shown that applying a quality glue after the hydro-seeding-mulching operation, in the same manner that tackifiers are applied to straw, is many times as effective as including the glue in the hydro-seeding-mulching slurry. Particularly effective was the Dow Mulch Binder XFS 4163-L. Rates as low as 20 gpa with 0.75 lb modifier and 86 lb of wood fiber in 344 gal water as a tackifier over 1,500 lb of fiber with seed and fertilizer gave a surface that was more resistant to rainfall impact than 60 gpa applied in the single slurry (Figure 8), or resistant for a much longer period than 20 gal in a single application (Figure 9). Plant emergence or growth were not adversely affected by splitting the application. Germination may be reduced and delayed by use of fertilizer with SBR. Using higher rates of seed will compensate for this loss. The low total volume of SBR required will call for careful applications.

There is a hazard to the seed in using highly effective mulches or additives. These products or combinations may retain enough moisture to allow germination when the moisture in the soil is too low to permit establishment. Simply covering the seed with soil may be more effective in that the seedbed will remain dry until enough moisture is available for both germination and growth.

B. Soil Binders

Plastic emulsions have been used for about a decade to bind surface soil particles for protection from wind and water erosion. Their use has been limited, however, by relatively high cost and by numerous reports of ineffectiveness and negative effects on plant establishment (Sheldon and Bradshaw 1977). Among the emulsions used are polyvinyl acetate homopolymers or vinyl acrylic copolymers, generally called PVA. Commercial versions are Aerospray 70, Crust 500, Curasol AK, Enviro, MGS, Stickum, Terra Krete, and Soil Bond. Soil Seal, similar in effectiveness, is a copolymer of methacrylates and acrylates. Another chemical group is styrene butadiene (SBR). All are an intimate mixture of high-molecular-weight polymeric particles dispersed in a continuous aqueous phase. They are basic ingredients in paint, glue, and other products.

1. Effectiveness and rate

Plastic emulsions give better initial protection than do other commonly used erosion-control practices. The optimum rate determined by

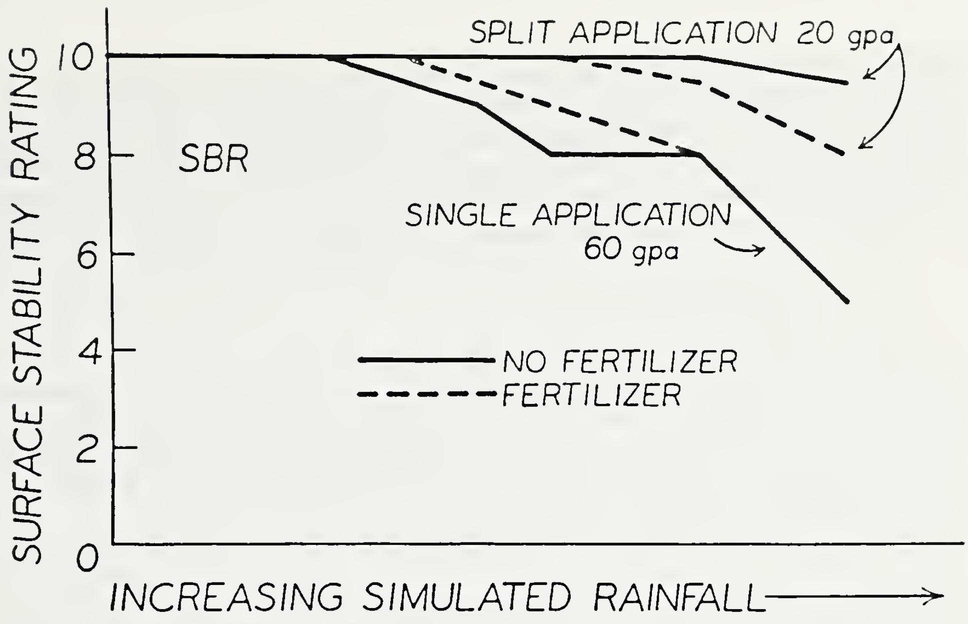

Figure 8. Effect of increasing rainfall on surfaces treated with a single application of SBR at 60 gpa and split applications of SBR at 20 gpa, with and without fertilizer.

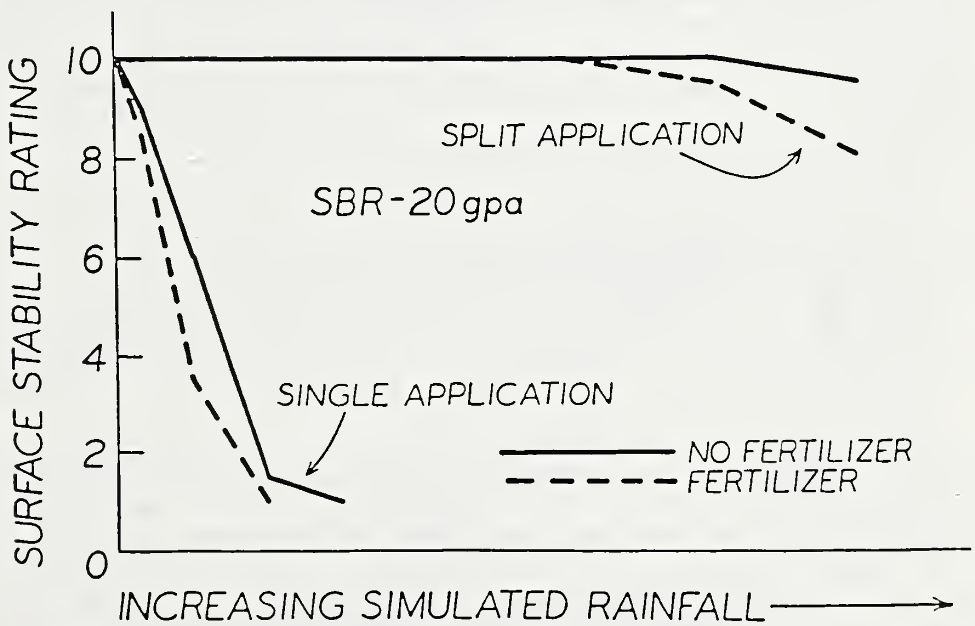

Figure 9. Effect of increasing rainfall on surfaces treated with SBR at 20 gpa, comparing single and split applications with and without fertilizer.

the California Department of Transportation is 1,000/lb acre of dry solids (about 200 gpa) for the polyvinyl acetates (750-1,100 lb/acre on various soils). Most emulsions are about 9 lb/gal and 55% solids. Recent tests compared PVA with an experimental SBR from Amsco Division Union Oil Company at rates of 500 and 1,000 lb/acre solids, SBR at 500 lb was similar in effectiveness to PVA at 1,000 lb.

2. Dilution rates

All products tested to date are sold as a liquid concentrate to mix with water. The amount of water used is critical. Figure 6 illustrates the relative effectiveness of dilution rates of 5:1 (water to PVA concentrate) to 40:1 at 1,000 lb of PVA solids per acre.

Dilutions of 5:1 to 10:1 PVA are obviously far more effective than higher dilutions (Fig. 6). Comparison of dilution rates of 1:1 with 10:1, show 4:1 to be too little water, with 5:1-7:1 optimum, 8:1 and 9:1 satisfactory, and 10:1 less effective. All of the above tests were conducted on dry sand. Emulsions were applied to a horizontal surface of 13 x 19 inches and allowed to cure at about 60 F for at least two days. The surface was then inclined at 1:1 (steeper than the natural angle of repose of sand). The surface was then exposed to artificial rainfall at 6 inches/hr, 3-mm drops, or 6 inches/hr composed of 2 inches/hr, 2-mm drops, plus 4 inches/hr as a mist. Some treatments survived over 120 inches of the latter type of rainfall.

The optimum dilution rate could be expected to be different with other products, on other soil materials, and with other soil-temperature and moisture conditions. Optimum dilution is far less critical for SBR. Tested were 6:1, 12:1, 24:1, and 36:1 at 500 lb/acre solids. The lower three dilution rates, all equal effective, were superior to the 36:1 dilution.

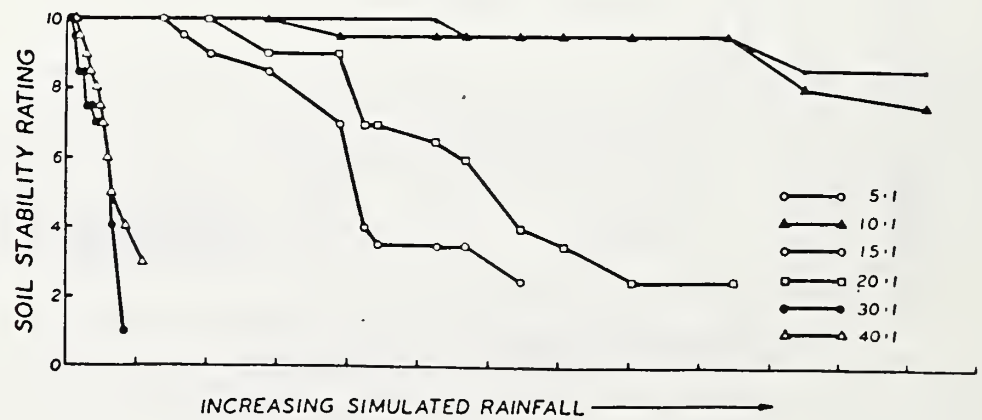

Figure 10. Effect of simulated rainfall on the surface stability of sand treated with 1,000 lb/acre PVA solids at various dilution rates.

The poor performances of commercial applications can often be traced to the use of too much water. When the emulsion is applied as a component of hydroseeding, a frequent practice, the water required to carry the wood fiber and other components is often greater than the desired PVA dilution. Hydroseeding machines will normally pump 3-5% fiber by weight. If the contract called for 1,500 lb fiber and 200 gpa PVA the dilution rate would be 30:1 at 3% and 18:1 at 5%. (Both the liquid and solid effect of the PVA as well as the possibility of an easier pumping effect of PVA are ignored in these calculations as a safety factor to avoid a plugged hydroseeder full of expensive components.) This means that the PVA must be applied separately--after the first application (containing the fiber, seed, and fertilizer). A material which is less restrictive as to dilution rates would then be advantageous by allowing a single rather than split application. However, the benefits discussed earlier of split applications allowing reduced chemical rates should easily make up for the cost of a second application.

3. Curing of emulsion film

A primary limitation of emulsions is the restriction placed on curing. The minimum curing temperatures generally recommended are 55 F for PVA and 40 F for SBR. Also required are proper drying conditions. Fog will prolong by many days the curing time of either emulsion, and rain before the emulsion is properly cured may prove the crust to be ineffective. A logical use of the materials would be when the construction project is halted for the winter. Unfortunately, however, weather conditions which halt construction are the same as those which slow the curing of emulsions.

4. Effect on plants

Plastic emulsions are not generally toxic to plants even if sprayed directly on them. They commonly reduce establishment, however, and delay emergence of grass seedlings. Grass seedlings may have a tip burn. These problems are apparently the effect of fertilizer used with the emulsion and seed, rather than the emulsion itself, and are particularly a problem on sandy soils, and not on clay soils. Fertilizing separately, after seeds have germinated, has avoided the problem of fertilizer burn.

The most practical way so far of offsetting reduced seedling numbers has been to increase the seeding rate. Doubling the rate of Blando brome from 50 lb to 100 lb/acre has generally compensated for plant losses due to fertilizer, and sometimes resulted in an increase in numbers, ground cover, and pounds of grass growth. Wood fiber is an essential part of an emulsion treatment, particularly if seeds are used. PVA emulsions will not stick seed or fertilizer to a soil slope. Unless a fiber is added the seed and fertilizer will wash off readily. Do not apply fiber and seed after the emulsion, for they will wash off.

5. Other considerations

Freezing temperatures destroy all uncured emulsions. Biological

activity also may limit the storage life of emulsions. Crusts formed by emulsions may shed most of the rainfall. Therefore they may limit plant establishment and growth in low-rainfall areas and soils of low water-holding capacity. Crusts are not self-healing. The treated area must be protected from vehicles and animals, and breaks should be repaired. Crusts will not survive frost heaving. The emulsion could be used very effectively with transplanted shrubs. A soil-active herbicide could be used with them to provide a weed-free erosion-control program.

VI. SOIL AND ROCK MULCHES

Soil and rock mulches are often overlooked as the most practical solution to plant establishment and soil protection problems. The microsites created by rough seedbeds or rock provide seed coverage, separation of seed and fertilizer, and a mulch effect.

The importance of microsites to the establishment of plants was illustrated by Evans and Young (1972). In their Nevada study, seedling emergence and the growth of downy brome, medusahead, and tumble mustard were favored by seed burial, pitting of the soil surface, and soil movement. Air temperatures were continuously measured at the soil surface and 3 cm above, and soil moisture from the surface to 1 cm deep, and at 3 cm. Results showed that depressed sites retain moisture longer at the surface and have more favorable atmospheric moisture and temperature regimes than the flat soil surface. Conditions are also created for more adequate soil coverage of the seeds, which in turn further modified their environment.

A practical approach on steep slopes, such as highway cuts, is the use of benches, serrations, or simply rough grading. The rough effect can often be achieved by simply eliminating the final grading operation. Special pitting equipment is available for nearly-level sites. "Track walking" (walking a tractor on a slope to create cleat marks) is widespread and very effective.

Mulches of crushed stone or gravel one inch deep provided more effective erosion control than 4,000 lb/acre of straw, and heavier rates of stone were even more effective (Meyer et al., 1972). Field observations in Nevada and California also show a ground-cover of gravel to be effective for reducing wind and water erosion and encouraging invasion by indigenous plant species.

VII. RELATIVE EFFECTIVENESS AND COSTS

Mulching practices vary considerably in cost and effectiveness. Sometimes the characteristics of the site to be stabilized determine the only practical treatment. Usually, however, there are alternative methods which should be considered.

Seed coverage and mulch should be the first consideration. Seed germination and plant establishment will be improved more by seed coverage than by any other treatment. Mulch treatments increase in effectiveness with both the amount of mulch per acre and the length of the fiber. While it is possible to apply excessive amounts of mulch,

economic considerations usually prevent it. The importance of fiber length, however, should not be overlooked. Increasing the fiber length (as from wood cellulose fiber to straw) may greatly increase the effectiveness of erosion control and germination (Kill et al., 1971; Perry et al., 1975). This relatively large increase in effectiveness can be achieved at little or no increase in cost. Even increasing the length of wood-cellulose fiber from a recycled paper product to virgin wood fiber improves results with little effect on cost.

The most expensive practice is not necessarily the most effective. For example, straw plus a tackifier is more effective for both erosion control and plant establishment than many of the more expensive treatments. A rough seedbed or covering the seed may be the cheapest and most effective treatment for establishing vegetation.

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VEGETATION AND MECHANICAL SYSTEMS

"For Streambank Erosion Control"

"Guidelines For
Streambank Erosion Control Along
The Banks of the Missouri River
From Garrison Dam Downstream To
Bismarck, North Dakota"

The guidelines for Streambank Erosion Control along the Banks of the Missouri River from Garrison Dam to Bismarck, North Dakota were produced through a Memorandum of Understanding between the

U.S. Army Corps of Engineers

Omaha District

and the

USDA Forest Service, Northern Region

and the

North Dakota State Forest Service

Authors

An Interdisciplinary team led by

Leon D. Logan, USDA Forest Service

State and Private Forestry

Missoula, Montana

February 1979

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One:

Conclusions/Recommendations

1. Sites that are revegetated need to be sloped to a specific angle, no steeper than 1 vertical to 1 horizontal.

2. Topsoil needs to be stockpiled and replaced or imported on the site to a depth of 4 inches. Fertilizer may need to be added.

3. Plant materials need to be genetically adapted to the site.

4. A community of plants needs to be re-established, not a monoculture.

5. Specific sites will need specified plant species.

6. Plant materials must be handled, stored and planted properly so that live, healthy plants are correctly planted.

7. Some site situations are more critical for revegetation than others.

8. Monitoring of the plantings and site erosion should be done for a minimum of 3 years.

9. Management of the re-established plant community is necessary.

Two:

Procedures

Two extensive library searches 1/ were made for published information on the reach of the Missouri River from Garrison Dam to Bismarck, North Dakota, relative to vegetation and streambank erosion control 2/.

An Interdisciplinary Team (I.D.) of Scientists 3/ assembled at North Dakota State University January 30-February 2, 1979 and, through their interdisciplinary efforts, this document was prepared. This team used the references from the library search, other publications brought with them to the meeting, and the varied education, training and field experience and individual talents to complete this document. An extensive review process was utilized to allow each individual to critically review the draft document and input into the final document.

1/ Westfornet computerized library search system
2/ See bibliography
3/ See Biographical Data

Three:

Introduction

OBJECTIVE

To provide generalized vegetative guidelines to assist planners in developing engineering project design and contract specifications for streambank erosion control. The stabilizing plant communities will generally be self-substaining and require a minimum of maintenance while providing streambank erosion control, esthetic, wildlife and human benefits.

SCOPE

These guidelines provide information on various engineering structures used in erosion control, site differentation, site preparation for revegetation, species to be used in revegetation, revegetation techniques, cost of revegetation materials and project monitoring.

SITE DESCRIPTION

These guidelines apply to the water-land interface and adjacent riparian area along the Missouri River from Garrison Dam (47° 30' N, 101° 27' 30'' W) on the north to the back-up waters of the Oahe Reservoir, roughly approximating the northern boundary of Emmons County (46° 36' 30'' N, 100° 37' 30'' W). This includes approximately 80 river miles (See Figure 1). Johnson et al. (7) 1/

The Northern Great Plains lies within a climatic regime described as dry subhumid Mesothermal, Johnson et al. (7). The average annual precipitation is substantially less than potential evapotranspiration. This generally restricts the decidous forest to low ground where soil moisture conditions are favorable. This region is subject to great fluctuations in weather conditions.

The climate of Burleigh County,North Dakota is typical of the area covered by this report. The relative humidity and rainfall are low. There is an abundance of sunshine, moderate snowfall and the prevailing winds are northwesterly. The diurnal and seasonal extremes of temperature are pronounced. The average frost free growing season runs from the first week in May to the last week in September. The mean annual precipitation is 16.5 inches, 70 percent of which occurs during the growing season, with 50 percent from May through July. The driest months are December, January and February when 0.5 inches are received as snow.

For Bismarck the mean frost free period is 136 days, the mean annual precipitation is 16 to 17 inches, the mean total hours of sunshine is 2,700 hours, the mean number of days with a maximum temperature of 90°F or greater is 23 days and the mean number of days with a minimum temperature of 32°F or less is 186 days. (20)

The west-central portion of North Dakota is included in the Glaciated Missouri Plateau section of the Great Plains Province, Fenneman (31). The Glaciated Missouri Plateau is divided into four regions: Coteau du Missouri, the Missouri Trench and two unnamed sections. The area that these guidelines apply to is within the Missouri Trench. The Missouri River floodplain varies in width from less than 1 mile at the northern

1/ Numbers in Parenthesis refer to references in the Bibliography

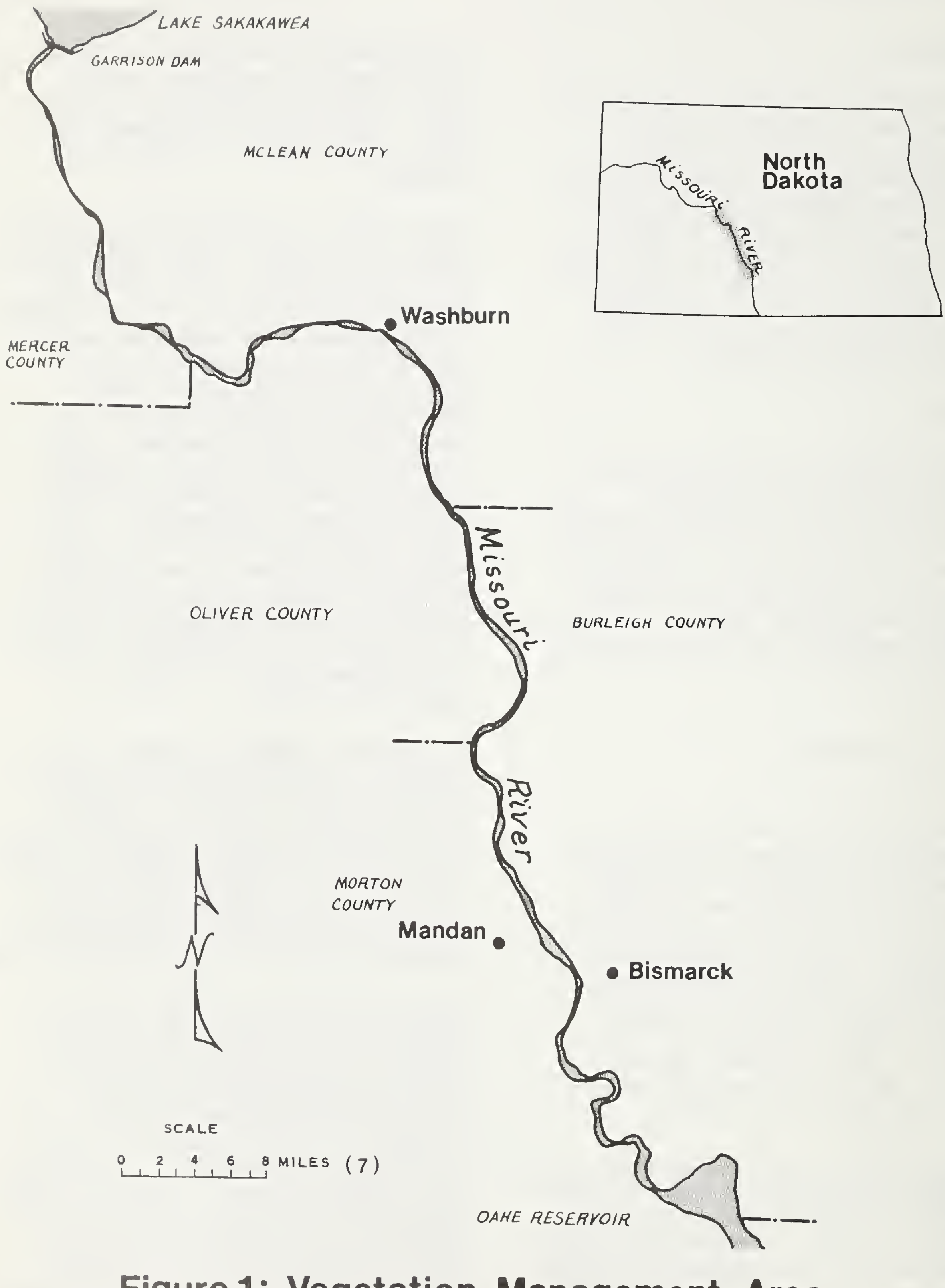


Figure 1: Vegetation Management Area

end near Garrison Dam to more than 7 miles just south of Bismarck. The river is a meandering one. Sediments settle out of the water in the Garrison Reservoir and the water released from the Garrison Dam is capable of picking up considerable sediment or in other words, is an extremely erosive force upon leaving the Garrison Dam.

The Missouri River Valley is underlain by the Hell Creek and Fox Hills formations of Cretaceous age. Superimposed on the Hell Creek formation are the Tullock and Ludlows, Cannonball and Tongue River formations of Tertiary age, which are exposed on the steep and dissected valley walls. The Sentinel Butte formation of Tertiary age is exposed near the Garrison Dam. The Missouri River Valley has well developed tributaries from the west, including the Knife, Heart and Cannonball rivers and underdeveloped tributaries from the east including Painted Woods, Snake, Burnt, Apple and Badger creeks. Therefore the Missouri River Valley floor consists of alluvium outwash and bedrock terraces. The layering of alluvium and outwash at various times is quite evident in the river cuts.

The soils of the area have formed in recent alluvium which ranges from sand to silty clay loam in texture, Omodt et al. (32). Alluvial soils usually have a grayish brown A horizon and a light grayish brown C horizon. Numerous layers of sediment often make up the soil profile, each layer deposited by a different flood. These individual layers often differ from each other in color, texture or both.

The four basic soil series present on the floodplain of the river are the Banks, Havre, Lohmiller and Gallatin.

The Banks series is found near present or former stream channels. These soils are excessively drained and are developed from course-textured recent alluvium. Sand and loamy sand are the dominant textures throughout the profile, but occasionally thin layers of loam or fine sandy loam occur. Color ranges from very dark grayish brown to brownish gray. Available water capacity is low and fertility is limited.

The Havre series usually occurs farther from the present river channel than the Banks series. Havre soils develop from medium to moderately fine-textured, calcareous, recent alluvium. Flood-deposited layers are usually medium textured,but layers of fine sandy loam, loamy sand amd silty clay are not uncommon. Color ranges from dark grayish brown to light brownish gray. Soils in this series are moderately permeable and have a high available water capacity.

The Lohmiller series is found on terraces some distance from the rivel channel. Soils comprising this series are usually moderately fine to fine silts and clays.

Soils of the Gallatin series form on poorly drained depressions and abandoned channels on the floodplain. Large amounts of fine and very fine clay particles are often a textured feature.

The soils of the floodplain have been only slightly modified by vegetation. Post flooding has continually removed or covered organic matter, lessening the effect of vegetation on soil formation. All of the soils of the floodplain are highly erodible.

At present, both prairie and forest vegetation occupy the steep valley walls rising above the Missouri River floodplain. Green needle-grass

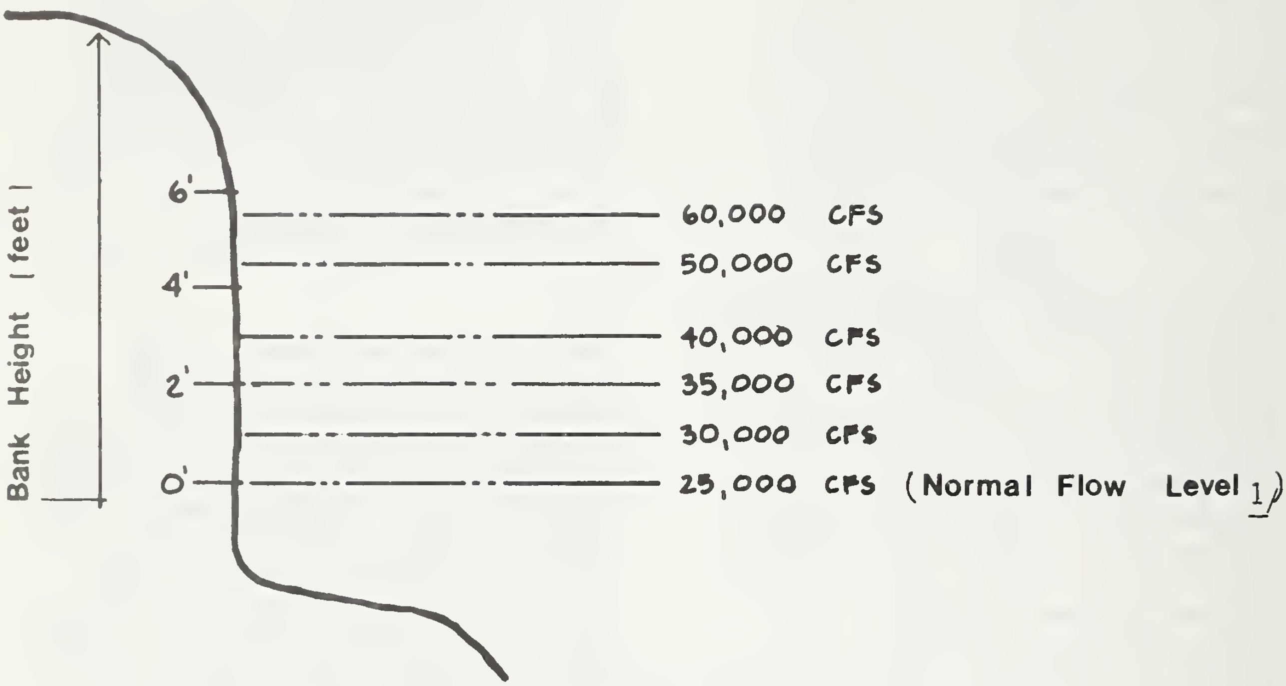


Figure 2: River Levels and Flows

Table 1: Recurrence Interval by Discharge and Duration

Discharge	Duration			Probability Of Not Ocurring (60days)
	6 Mo.	60 Days	1 Day	
60,000 CFS	-	1/100 Yrs.	1/20 Yrs.	99%
50,000 CFS	1/100	1/10	1/5	90%
40,000 CFS	1/10	1/3	1/2	67%
35,000 CFS	1/3	1/2	1	50%
30,000 CFS	1/2	1	1	1%
25,000 CFS	1	-	-	-

1/ (Normal Flow Levels) - occurs generally from April 15 - May 15 until Nov. 15
CFS = Cubic feet per second

(Stipa viridula), needle-and-thread (Stipa comata), little bluestem (Andropogon scoparius), western wheatgrass (Agropyron smithii), side-oats grama (Boutelova curtipendula) and blue grama (Boutelova gracilis) are the most common grasses in moderate to well-drained prairies. On wet prairie sites, big bluestem (Andropogon gerardi), little bluestem (Andropogon scoparius), switchgrass (Panicum virgatum), and Canada wild-rye (Elymus Canadensis) are common grasses. In wooded ravines Bur Oak (Quercus macrocarpa), green ash (Fraxinus pennsylvanica) aspen (Populus tremuloides), box elder (Acer negundo) and American Elm (Ulmus americana) are the most common.

The floodplain currently is a mosiac of cultivated fields, marshes, sand dunes, sand bars, brushland and forest. Corn,wheat, oats, sugar beets and alfalfa are common crops. The forests of the floodplain consist of mainly cottonwood (Populus deltoides), peach-leaved willow (Salix anhygdaloides), green ash (Fraxinus pennsylvanica), box elder (Acer negundo), American elm (Ulmus americana) and bur oak (Quercus macrocorpa). These floodplain forests vary depending upon their age. Young forests consist mainly of willows and cottonwoods. The willows are gradually replaced by box elder and green ash and ultimately mature floodplain forests consist of cottonwood, green ash, American elm and bur oak.

The prairie on the floodplain river is similar to the wet prairie discussed above. Marshes dominated by sedges (Carex spp.) and cattails (Typha spp.) are found in old stream channels.

The Missouri River readily erodes the river bank no matter what the vegetation or the land use is along the river. The eroded banks vary from a few feet to steep banks 15-20 feet high. This erosion necessitates the use of engineering structures and bank vegetation to control the bank erosion.

RIVER LEVEL AND FLOW RATE

Table No. 1 shows the frequency of various flows and their duration with 25,000 cfs being the normal flow from late spring through fall. Thus a 40,000 cfs flow with a duration of 6 months can be expected to occur once every 10 years, a 60,000 cfs flow with a duration of 60 days can be expected to occur once every 100 years and a 60,000 cfs flow with a duration of 6 months should not occur.

Figure 2 shows the approximate water level corresponding to various river flows, using the level of 25,000 cfs as the reference. Thus at a flow of 40,000 cfs, the river level will be approximately 3 feet above the reference level.

Flows may be increased from the normal 25,000 cfs in June or July in order to decrease excess water stored behind the Garrison Dam before freeze up. Flows after November 15 through April 15 normally are about 15,000 cfs.

Four:

Typical Structure Design and Placement

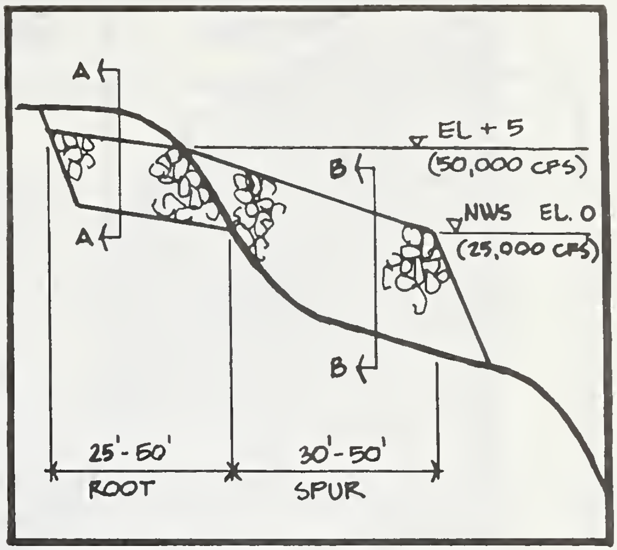
BACKGROUND

Banks of the Missouri River are easily erodible. Left unprotected, the river would continually modify its course by erosion in one area and sandbar development in another area. However, the Corps of Engineers has an established commitment to reduce the massive erosion that would occur on specific sites if the banks were left unprotected. Through extensive experience, the Corps has settled on a combination of permenant force-abating structures that are strategically located.

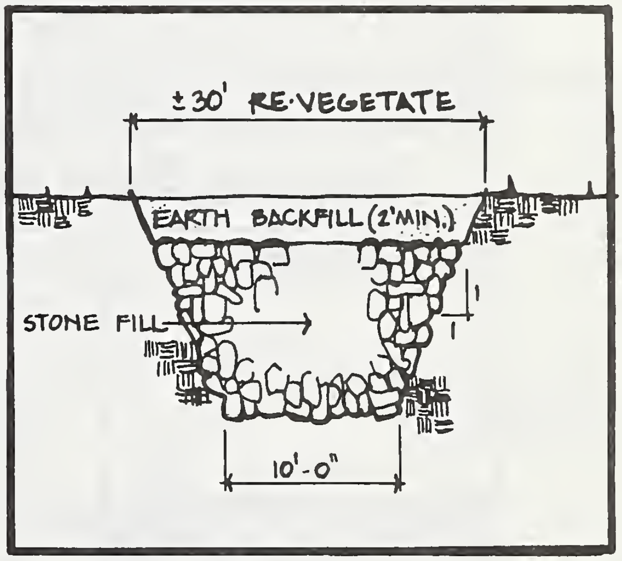
Two typical force-abating structures commonly used in bank stabilization are revetments and hardpoints. A revetment can be constructed from many hard materials and is placed horizonal to the bank on the "toe" of a normal discharge beach. Figure 4 illustrates the typical placement of revetments on a low and high-bank beach relative to the normal daily flow rate. A hardpoint is typically a rock filled projection extending perpendicular from the bank and is illustrated in Figure 3. In specialized cases where sandbars must be stabilized, reinforced sandfilled dikes (Figure 5) may be used.

An example of a typical demonstration structure layout on an eroding streambank is presented in Figure 6. Demonstration structure layouts intentionally leave 250 to 1,000 feet and more of unaltered bank between structures.

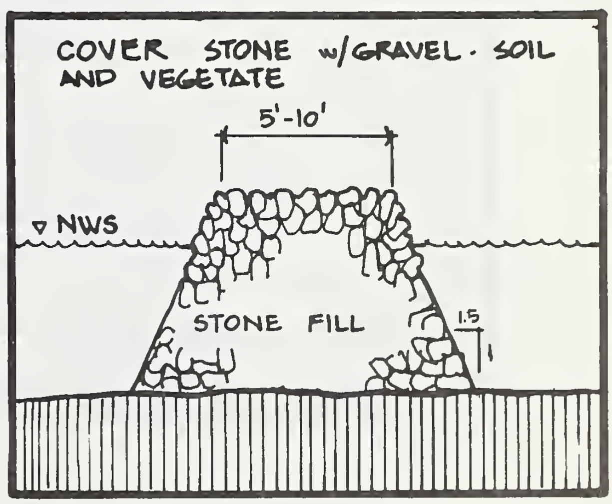
Demonstration structure layouts intentionally leave spaces of unaltered bank between structures. Unprotected requirements range from 250



Profile

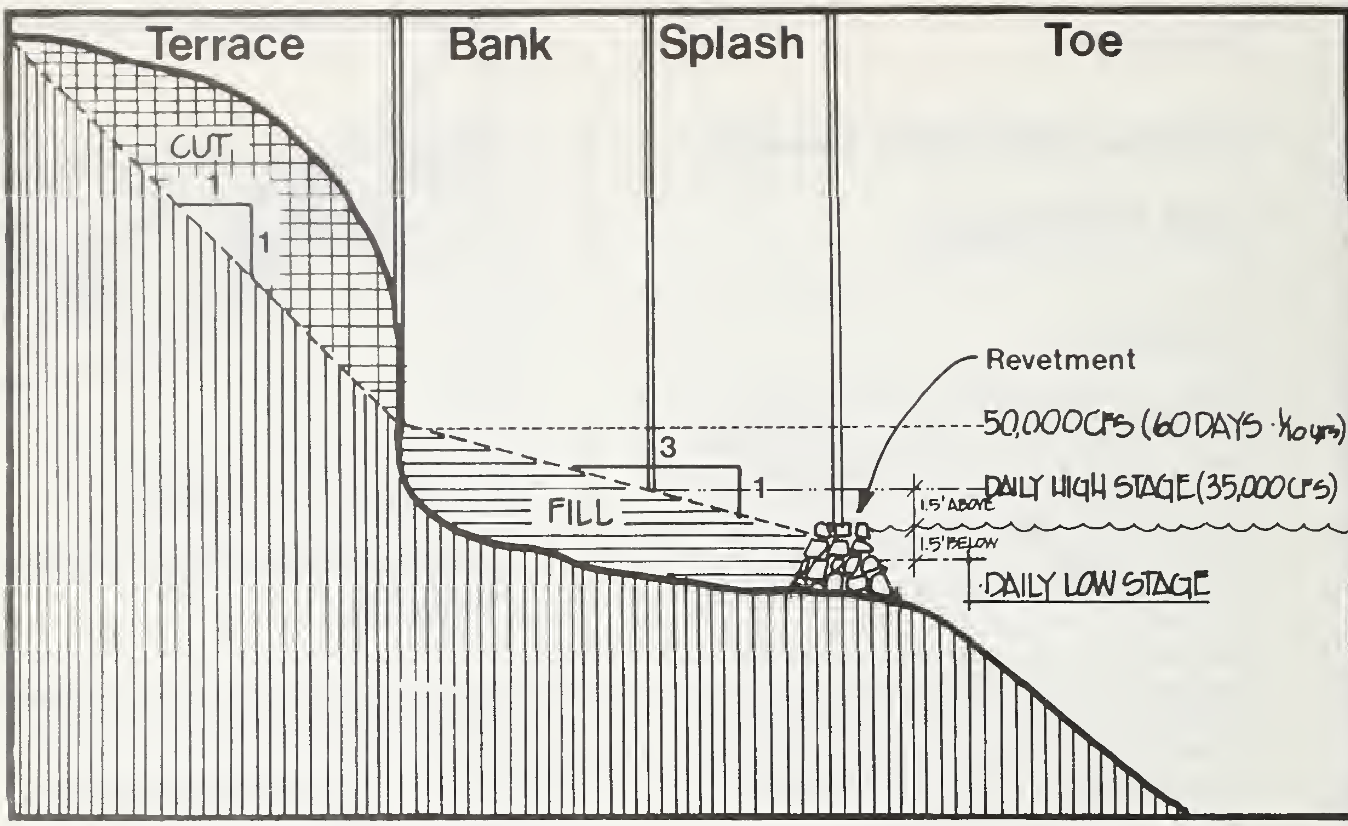


Section A-A

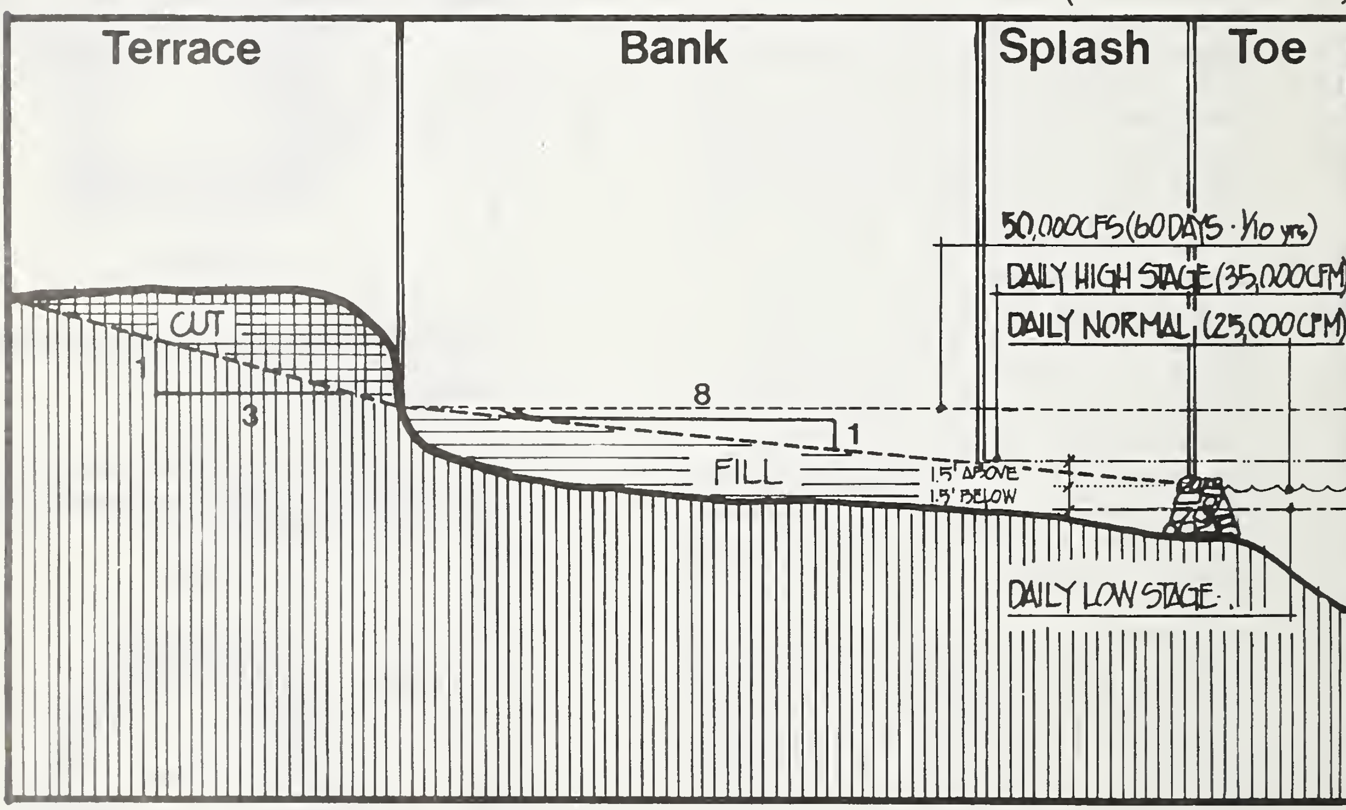


Section B-B

Figure 3: Hardpoint



1 Maximum Slope Limits . . . . (NO SCALE)



2 Minimum Slope Limits . . . . (NO SCALE)

Figure 4: Constructed Slopes

feet to 1,000 feet and more in length. Each structure includes a "root" (hardpoints) or "refusal" (revetments) which extends landward, perpendicular to the bank a sufficient distance to allow for the anticipated interstructure erosion. Roots and refusals generally range from 25 feet to 100 feet in length.

THEORY

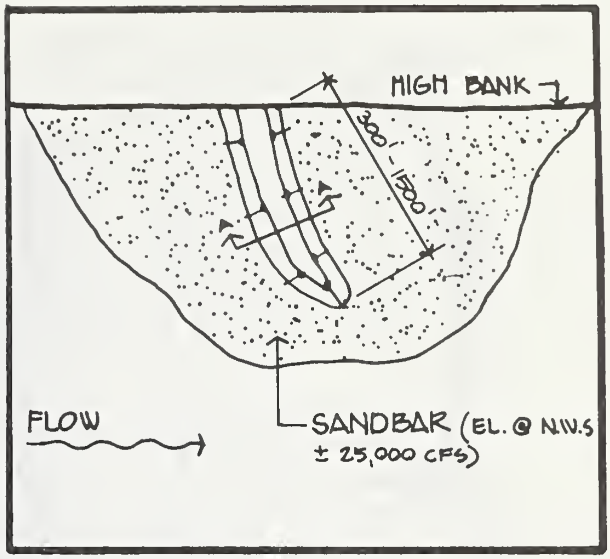
The extent of the interstructure erosion is limited by the prevailing water depth and velocity riverward of the structure alignment (the theoretical line connecting the riverward extremity of all the structures in the system); by the bank height and composition (material types); and by the structure spacing. As the river erodes into the bank, the flow path becomes longer as the water entering the erosion "bight" must return to the original bank location at the next downstream structure. Accordingly, the energy gradient becomes proportionally less as the size of the "bight" grows.

Thus, at a given river stage (discharge) the "bight" ceases to grow when the energy gradient is no longer sufficient to remove material from the bankline.

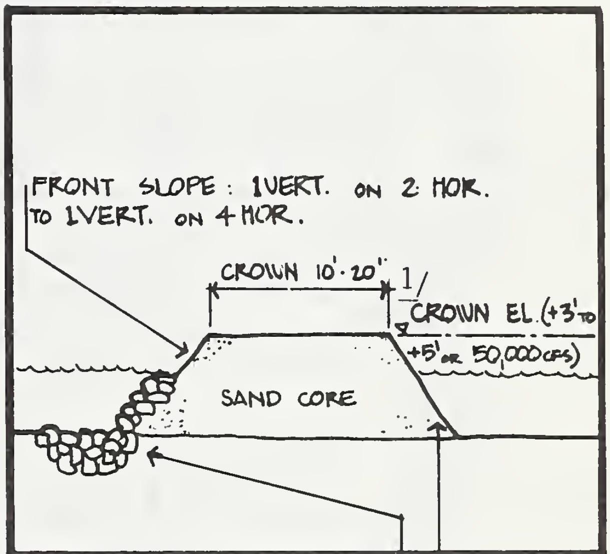
The resulting configuration and cross section of the "stable" bankline is shown in Figure 6. However, the configuration will remain stable only as long as extended duration flows do not exceed the flow-level which created that configuration.

NEED FOR VEGETATION

Planting vegetation on the banks behind revetments and on top of hardpoints are a must to stabilize easily erodible constructed slopes. These plantings should be accomplished shortly after con-



Plan



Stone fill toe and upper bank paving

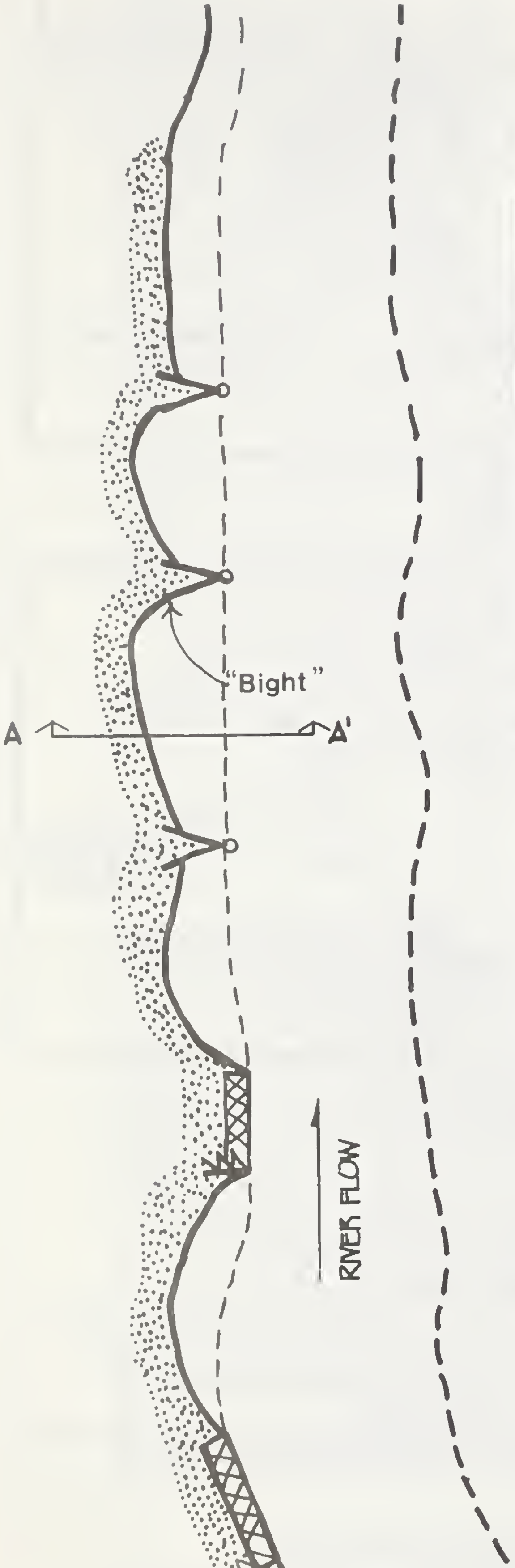
Backslope varies 1 vertical on 4 horizontal to 1 vertical on 8 horizontal

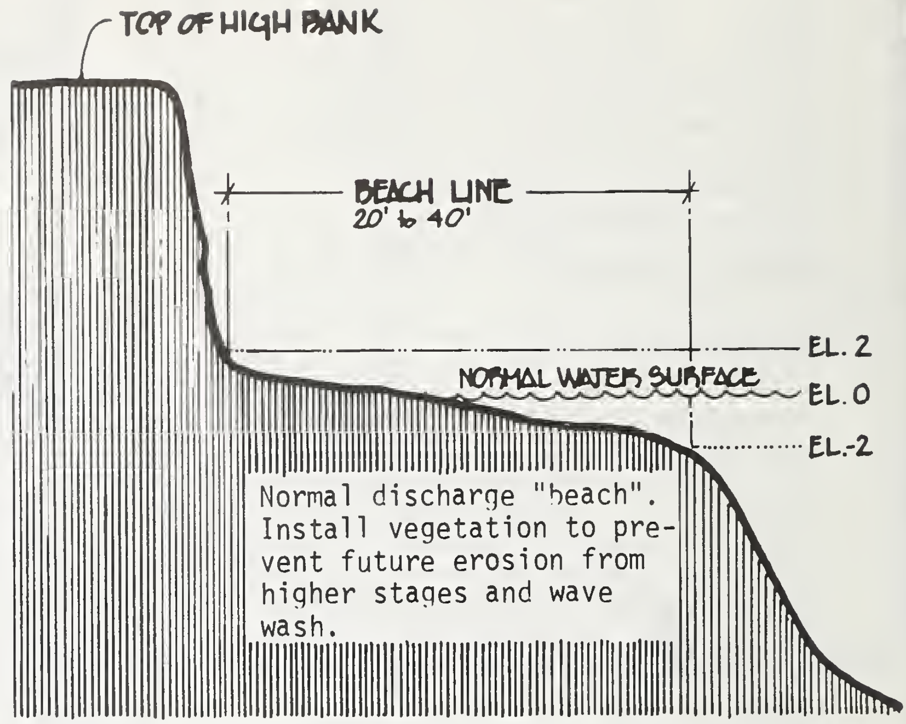
Section A-A

1/ Treat slopes and crown with combination (or singly) of stone, gravel, structural mesh and vegetation.

NOTE: Crown elevation generally level for any given structures.

Figure 5: Sandfill Dike





Section A-A'

(After erosion back to stable condition at normal discharge)

Note: Actual inter-structure gaps (unprotected bankline) range from 250 feet to 1000 feet in length.

Legend

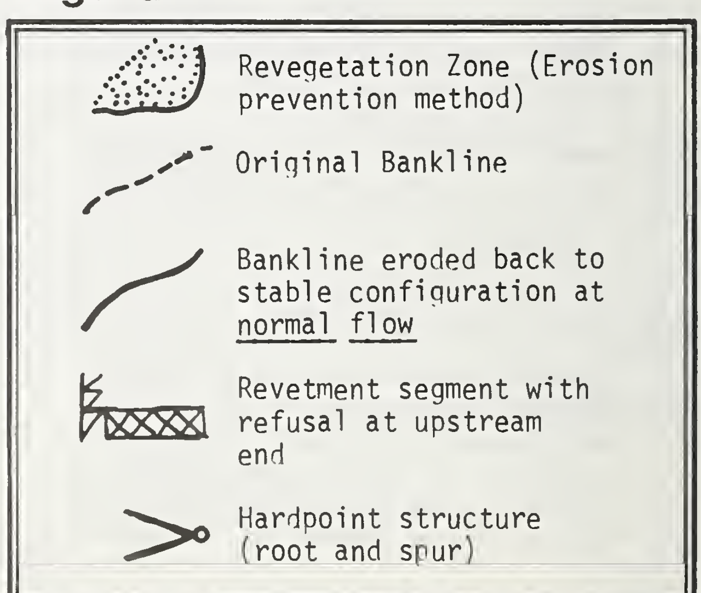


Figure 6: Structure Spacing

struction of the structure to prevent unnecessary erosion prior to planting.

Planting vegetation along the "beach" formed along the eroded bankline at normal water flow rates should reduce or prevent additional erosion at higher river stages and erosion due to wave-wash action. Such plantings may reduce the need for as many expensive structure developments by increasing the length of unprotected (except for vegetation) shoreline between structures. However, it may be necessary to delay vegetational plantings in the interstructural area until a near-stable bankline is formed. In addition, some bank grading may be necessary to allow establishment of the vegetation.

BANK ZONE DESCRIPTION

The U.S. Corps of Engineers has divided the stable bank into three zones (terrace, bank and splash zones). These zones are not precise and distinct since the river level varies daily and seasonally, but they should be useful in subsequent discussions. Figure 4 illustrates the location of each zone, the following is a description of each zone:

Splash zone - that portion of the bank between the normal high-water and normal low-water flow rates. This is the zone of highest stress. The splash zone is exposed frequently to wave-wash, erosive river currents, ice and debris movement, wet-dry cycles and freezing thawing cycles. This section of the bank normally would be inundated throughout most of the year, at least 6 months/year. The water depths will fluctuate daily, seasonally and by location within the splash zone.

Bank zone - that portion of the bank usually above the normal high-water level; yet, this site is still exposed periodically to wave-wash, erosive river currents, ice and debris movement and traffic by animals or man. The site is inundated for a 60-day duration once every 2 to 3 years (Table 1). The water table in this zone frequently is close to the soil surface due to its closeness to the normal river level.

Terrace zone - that portion of the bank from the bank zone inland which usually is not subjected to erosive action of the river except during occasional time "flooding" by the river. This zone may include only the level area near the crest of the unaltered "high bank" or may include sharply sloping soils on high hills bordering the river. The terrace zone probably will include much of the "cut" area on constructed slopes (Figure 4), especially on sharp 1 vertical to 1 horizontal slopes. This zone generally is subjected to periodic dry periods with soil moisture primarily dependent on characteristic rainfall of the area.

Five:

Site Preparation

SLOPING

River banks within the designated project areas will be treated with various combinations of structures and vegetation for protection from further erosion damages. Figure 4 indicates both maximum and minimum slope limits. For steeper banks, the cut would generally be a 1 vertical to 1 horizontal slope. For the fill area below the cut to the toe-in, the slope would generally be constructed on a 1 vertical to 3 horizontal slope.

For the more gentle sloping banks needing erosion protection, the cut slope would be about 1 vertical to 3 horizontal and the fill slope would be about 1 vertical to 8 horizontal to the toe-in.

The terrace, bank and splash zones are superimposed on these typical cross-sections to indicate their relative position to various water levels and cut and fill slopes.

Daily normal water level (25,000 cfs) generally fluctuates about 3 feet below Garrison Dam.

STOCKPILING TOPSOIL AND REPLACEMENT

In a 1960 U.S. Army Corps of Engineers study (23), the soils consisted primarily of sandy silt and silty fine sand with some clay soils at varying heights above the water surface.

A vegetation study along this stretch of river was conducted by Johnson, et al (7). The authors indicated that soil profile development is minimal with only A and C layers usually distinguishable.

Most of the soils along the river banks are highly susceptible to erosion when saturated or from wave action. Therefore, disturbed sites will erode quite readily if protection is not attained.

Recommendations:

All areas that will be vegetated should have a minimum of 4 inches of topsoil uniformily spread across the cut and fill slopes. Usually the topsoil is considered the surface soil high in organic matter. Availability of topsoil at each site will need to be determined since it may vary from 1 inch or less to several feet thick. If greater than 4 inches of topsoil is available, the contractor may choose to stockpile the topsoil for later use. However, if economics dictate or topsoil is unavailable at the site, topsoil can be imported. Imported topsoil preferably should be "black" (greater than 1.5 percent organic matter) sandy loam, loamy sand, or loam soil textural classes. The "black" soil color indicates a high organic matter essential to establishing and maintaining vigorous vegetation.

Although stands of vegetation can be established with greater difficulty and more time with other techniques, the success of bank stablization with vegetation may well depend on topsoiling.

SLOPE PROTECTION

Slope protection requirements necessary for the establishment of vegetation are dependent upon the following variables. (See Figures 3, 4 and 5).

1. Type of vegetation

2. Slope angle
3. Slope materials
4. Formation on slope relative to various flow levels.
5. Interface with structural measures.
6. Exposure to surface runoff.
7. Exposure to prevailing sun and wind directions.
8. Exposure to traffic by man and animal.

Factors 1 through 4 are particularly interdependent and can be combined into many acceptable configurations which would not require special slope treatment.

Factor 5 can possibly be utilized to eliminate the requirement for special slope treatment; for example, planting could be made through (or prior to placement of) a layer of course gravel, cobbles or even small stone.

Factor 6, surface runoff, can usually be handled by proper grading of the terrace zone to conduct surface runoff away from newly vegetated slopes and into locations where adequate drainage measures exist or can be installed.

Factor 7, adverse sun or wind exposure, will generally require special surface treatment to control surface moisture gain or loss, as appropriate.

Factor 8, pedestrian, vehicles or animal traffic, should be eliminated by fencing or other measures.

Specific measures for slope protection, when necessary, shall be part of the planting instructions for the specific site and plant types involved.

At present there is a product on the market that retains soil moisture and might be applicable for slope protection purposes. It is a hydrophobic cellulose starch known as Sorbex 200 1/. It is produced by Sorbex Products Company, Incorporated, Bismarck, North Dakota.

Also two chemicals are available that impede surface runoff. They have been tested by the Geotechnical Laboratory, U.S. Army Engineers Waterway Experiment Station, Vicksburg, Mississippi. Application of this compound for slope protection should be explored further.

1/ USDA-Forest Service does not endorse any commercial product.

Six:

Adapted Vegetation by Bank Zone

Vegetation to aid bank stabilization must be selected for the different sites encountered on the river bank. The typical bank zones (splash, bank and terrace) are described in the section on structure design and placement (pages 11 to 15). These zones are only approximate since the river level varies daily and seasonally; therefore, the area classified as the bank zone during May may be the splash zone in August when a higher daily flow rate is released from the Garrison Dam to reduce the impounded water. As a result, a community of species and specific planting patterns will be suggested to allow natural selection to differentially select the species most adapted to that specific microenvironment. In addition, only species naturally adapted to North Dakota commonly occurring in environments similar to those anticipated in each zone will be suggested. Figure 7 summarizes the most desirable species to revegetate the various bank zones. The following is a detailed discussion by bank zone of species selected

SPLASH ZONE

This section of the bank will be inundated throughout much of the year and is the zone of highest stress from river action. Plants used in the splash zone should have rhizomes (underground stems) that can regenerate topgrowth rapidly following removal by river action.

Species that commonly occur in similar environments are the submerged and emergent aquatic plants such as Typha, Scripus, Juncus, Polygonum and Phragmites. Therefore to vetetate the splash zone, it is suggested that a mixture of cattails; softstem, hardstem and American bulrush; and common reed should be planted. If additional diversity is desired in the plant community other species listed in Table 2 can be added.

BANK ZONE

The bank zone usually is above the normal water level. However, high discharge rates are to be expected causing seasonal inundation and a 60-day inundation can be anticipated once every 2 to 3 years (Table 1). The water table is fairly close to the surface even at normal flow rates due to the proximity of the river. Graded bank zones will range from 1 vertical to 8 horizontal to 1 vertical to 3 horizontal slopes and may have fill material deposited in this site. Consequently, a mixed soil condition likely will be encountered.

The bank zone in an undisturbed state will support a variety of grasses and some shrub species like willows and dogwood. In revegetating the bank zone, flood tolerant grasses like reed canarygrass, creeping foxtail and prairie cordgrass should be planted (preferably sodded) to obtain a quick cover. Shrub species like peach-leaf willow, yellow willow and red osier dogwood should be systematically planted into the grasses because ultimately these shrubs should provide most of the plant cover. If the grasses are seeded on the higher elevation bank areas, crownvetch and sweetclover should be added to the grass seed mixture to provide some soil fertility (nitrogen). Other grass and shrub species listed in Table 3 can be used to add

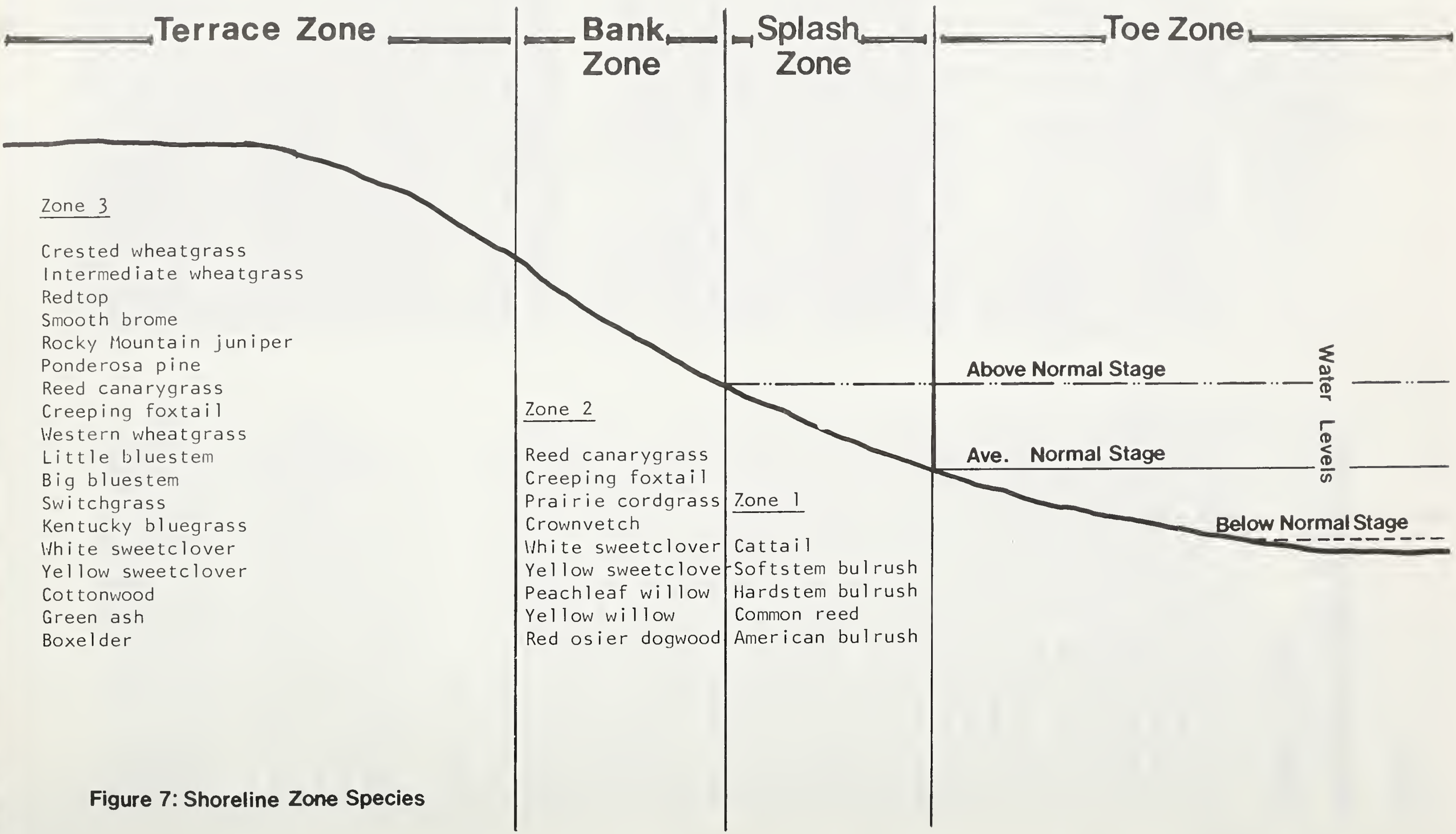


Figure 7: Shoreline Zone Species

Table 2

SPECIES RECOMMENDED FOR REVEGETATING THE SPLASH ZONE

SPECIES			
COMMON NAMES	SCIENTIFIC NAME	AVAILABILITY OF PLANT MATERIALS	METHOD OF PLANTING
Cattail	Typha latifolia	Local collection of rhizomes	Sprigging
Sofstem bulrush	Scirpus validus	Local collection of rhizomes	Sprigging
Hardstem bulrush	Scirpus acutus	Local collection of rhizomes	Sprigging
American bulrush	Scirpus americanus	Local collection of rhizomes	Sprigging
Swamp smartweed	Polygonum coccineum	Local seed collection	Seeding
Pale smartweed	Polygonum lapathifolium	Local seed collection	Seeding
Giant mannagrass	Glyceria grandis	Local seed collection	Seeding
American mannagrass	Glyceria striata	Local seed collection	Seeding
Common reed	Phragmites communis	Local collection of rhizomes & seed	Sprigging & seeding

Table 3

SPECIES RECOMMENDED FOR REVEGETATING THE BANK ZONE

SPECIES			
COMMON NAME	SCIENTIFIC NAME	AVAILABILITY OF PLANT MATERIALS	METHOD OF PLANTING
Grasses			
Reed canarygrass	Phalaris arundinacea	Commercial seed lot	Seeding, sprigging & Sodding
Creeping foxtail	Alopecurus arundinaceus	Commercial seed lot	Seeding
Northern reedgrass	Calamagrostis inexpansa	Local collection of seed & rhizomes	Seeding & sprigging
Prairie cordgrass	Spartina pectinata	Local collection of seed & rhizomes	Seeding & sprigging
Meadow fescue	Festuca elatior	Commercial seed lot	Seeding
Legumes			
White sweetclover	Melilotus alba	Commercial seed lot	Seeding
Yellow sweetclover	Melilotus officinalis	Commercial seed lot	Seeding
Crownvetch	Coronilla varia	Commercial seed lot	Seeding
Shrubs			
Peachleaf willow	Salix amygdaloides	Limited commercial	Bare rootstock
Diamond willow	Salix rigida	Limited commercial	Bare rootstock
Sandbar willow	Salix exigua	Local cuttings	Bare rootstock
Yellow willow	Salix lutea	Commercial	Bare rootstock
Bebbs willow	Salix bebbiana	Local cuttings	Bare rootstock
Red osier dogwood	Cornus stolonifera	Commercial	Bare rootstock
Hawthorn	Crataegus chrysocarpa	Commercial	Bare rootstock

diversity to the plant community in this zone, but these species should only compliment and never totally replace the previously listed species.

TERRACE ZONE

The terrace zone includes the bank areas usually not exposed to river action except for occasional true flooding and the generally level land from the river landward. The undistrubed terrace zone is naturally an open gallery forest with many grassland species intermixed. When disturbed, this area has the highest potential for supporting vegetation and should be the easiest to revegetate. Disturbance will occur in this area from land based construction of erosion control structures. Graded slopes will cause different site capabilities to the level terrace areas since surface erosion and mass slumping could occur; consequently, the graded slopes must be properly protected. Drought, compared to flood tolerance on previous zones, will be the major factor affecting plant survival. However, if properly protected,and adequate rainfall, the terrace zone can provide a mixture of woody and grassland species that are vital in erosion control and important in wildlife habitat, esthetics and recreation.

Species selected for revegetating the terrace zone should consider the normal woody-plant successional sequence found in natural revegetation of stablized sandbars. Initially willows and cottonwoods will establish with a cottonwood forest developing. This is gradually replaced by boxelder and green ash forest and finally a green ash and bur oak forest.

Initial revegetation work should involve seeding grasses and legumes for a quick vegetation cover. Native grass species used on the terrace zone should include a mixture of reed canarygrass, creeping foxtail, western wheatgrass, little bluestem, big bluestem, switchgrass and Kentucky bluegrass. Crested and intermediate wheatgrass, redtop and smooth brome are tamegrass well adapted to this environment which could be added to the seed mixture to improve grass establishment. White and yellow sweetclover should be included in the seed mixture to help add soil fertility and excellent wildlife cover.

Trees and shrubs should be transplanted into the establishing grasses to re-establish the naturally occurring gallery forest. Cottonwood, green ash, boxelder, juniper, Rocky Mountain juniper and ponderosa pine trees should make up the backbone of the woody species used on the terrace zone. Willows can be included near the bank zone. Other woody species from Table 4 can be added to the community for diversity and cost reasons if desired.

SPECIAL SITES

Hardpoints and sand dikes: The top of hardpoints should have a similar environment to the terrace except the soil depth will be much less. Grasses and trees listed in the terrace zone (Table 4) should be suitable for this area. Sand dikes should be seeded to more flood tolerant grasses like reed canarygrass, creeping foxtail and prairie cordgrass.

Roadways and construction sites: Roadways, storage sites and related areas will require some revegetation if markedly disturbed in the construction phase. These sites usually can be selectively treated by following normal vegetative planting practices. These sites usually will be quite similar to the terrace zone, but specific plans should be developed for each individual site.

Table 4

SPECIES RECOMMENDED FOR REVEGETATING THE TERRACE ZONE

(Includes the hard points and dikes 1/)

SPECIES COMMON NAME	SCIENTIFIC NAME	AVAILABILITY OF PLANT MATERIALS	METHOD OF PLANTING
Grasses			
Reed canarygrass	Phalaris arundinacea	Commercial seed lot	Seeding, sodding
Creeping foxtail	Alopecurus arundinaceus	Commercial seed lot	Seeding
Quackgrass 2/	Agopyron repens	Commercial seed lot	Seeding or sodding
Western wheatgrass	Agopyron smithii	Commercial seed lot	Seeding
Crested wheatgrass	Agropyron desertorum or Agropyron cristatum	Commercial seed lot	Seeding
Intermediate wheatgrass	Agropyron intermedium	Commercial seed lot	Seeding
Streambank wheatgrass	Agropyron riparium	Commercial seed lot	Seeding, sprigging
Redtop	Agrostis stolonifera	Commercial seed lot	Seeding
Little bluestem	Andropogon scoparius	Commercial seed lot	Seeding
Big bluestem	Andropogon gerardi	Commercial seed lot	Seeding
Switchgrass	Panicum virgatum	Commercial seed lot	Seeding
Smooth brome	Bromus inermis	Commercial seed lot	Seeding, sodding, sprigging
Kentucky bluegrass	Poa pratensis	Commercial seed lot	Seeding, sodding
Legumes			
White sweetclover	Melilotus alba	Commercial seed lot	Seeding
Yellow sweetclover	Melilotus officinalis	Commercial seed lot	Seeding

1/ It is recommended that only grasses and legumes be used on the hard points and dikes.

2/ Weed - not allowable for sale in N.D.

Table 4 (cont.)

Trees and Shrubs	SCIENTIFIC NAME	AVAILABILITY OF PLANT MATERIALS	METHOD OF PLANTING
Hawthorn	Crataegus chrysocarpa	Commercial	Bare rootstock
Cottonwood	Populus deltoides	Commercial	Rooted cuttings
Quaking aspen	Populus tremuloides	Commercial	Rooted cuttings
Green ash	Fraxinus pennsylvanica	Commercial	Bare rootstock or container
Boxelder	Acer negundo	Commercial (limited)	Bare rootstock
Juneberry	Amelanchier alnifolia	Local Collection	Bare rootstock or seed
Choke cherry	Prunus virginiana	Commercial	Bare rootstock
Bittersweet	Celastrus scandens	Commercial (limited)	Bare rootstock
Nannyberry	Viburnum lentago	Commercial	Bare rootstock
American elm	Ulmus americana	Commercial (limited)	Bare rootstock
Woods rose	Rosa woodsii	Commercial (limited)	Root pads, root and stem cuttings
Honeysuckle	Lonicera tatarica	Commercial	Bare rootstock
Virgins bower	Clematis ligustifolia	Local Collection	Seeding
Virginia creeper 1/	Parthenocissus inserta	Commercial	Bare rootstock
Wild grape	Vitis riparia	Commercial	Bare rootstock
Bur oak	Quercus macrocarpa	Commercial	Container
Buckbrush	Symphoricarpos occidentalis	Local Collection	Seeding
Bullberry	Sheperdia argentea	Commercial	Bare rootstock
Juniper	Juniperus communis	Commercial	Bare rootstock
Rocky Mountain juniper	Juniperus scopulorum	Commercial	Bare rootstock
Russian olive	Elaeagnus angustifolia	Commercial	Bare rootstock & container
Silverberry	Elaeagnus commutata	Commercially limited	Container
Buckthorn	Rhammus davurica	Commercial	Bare rootstock
Skunkbrush	Rhus trilobata	Commercially limited	Bare rootstock
Ponderosa pine	Pinus ponderosa	Commercial	Bare root & container

1/ Common name is a problem in the trade because several different species are referred to as Virginia Creeper. This can be overcome by requesting material using the scientific name.

Seven:

Revegetation and Cultural Techniques

PLANTING DESIGNS BY ZONES

The project manager should recognize the differences in planting sites aligning the river bank. Often the different planting sites or zones intergrade one into another. These zones may be quite narrow in width or difficult to distinguish. Consequently, the entire bank should be treated as a unit, with a systematic arrangement of plants and treatment practices. The proposed treatments should be designed to maximize existing equipment, manpower and other resources. Proper care in the selection of planting stock and implementation of realistic planting practices is required. Most sites are difficult to treat when compared to agricultural lands. Thus, plant materials must be carefully handled to assure establishment and survival.

The entire slopes should be treated to furnish a maximum array of plants capable of providing proper ground cover for erosion protection, wildlife habitat, and to appeal to recreation uses. As much as possible, native species are recommended and designed to the sites where they are best adapted. Sufficient numbers of plants and combinations of species will be used to allow for natural selection to occur. This will better assure the development of a suitable composition of species in a natural community.

SPLASH ZONE

This area cannot be successfully planted by direct seeding since this area will be inundated most of the year. Transplanting adapted species during low water release periods is the most practical approach. Transplanting aquatic species as "reed rolls", a system reported and described by Seibert (12), is recommended. This practice is shown diagramically in Figure 8. In addition, rhizomes, sod or clumps of adapted species could be systematically transplanted into this zone to develop the community. The reed rolls and other transplants must be held in place using mechanical or supportive structures until the plants are well established. Refer to the following sections for instructions in preparing, planting and anchoring reed rolls, sodding or sprigging.

The splash zone will be subject to flooding and scouring by river action. Serious, prolonged flooding can destroy newly established plantings or scouring by the river may remove transplants prior to adequate rooting; therefore, a followup treatment may need to be considered or planned as part of the contract to establish the vegetation.

BANK ZONE

Sites near the water's edge should be protected to prevent erosion by wave action. If only mild wave action is anticipated sodding of flood tolerant grass species like reed canarygrass should provide a rapid bank stabilization. Usually the sod must be held in place with small wooden pegs or wire netting until the sod roots adequately. High quality sod can root in 2 to 3 weeks. If more severe erosive action is anticipated the slopes should be further protected using a combination of supportive measures. Supportive measures that have performed adequately in similar areas include willow barriers, fascines, wattles and pav-

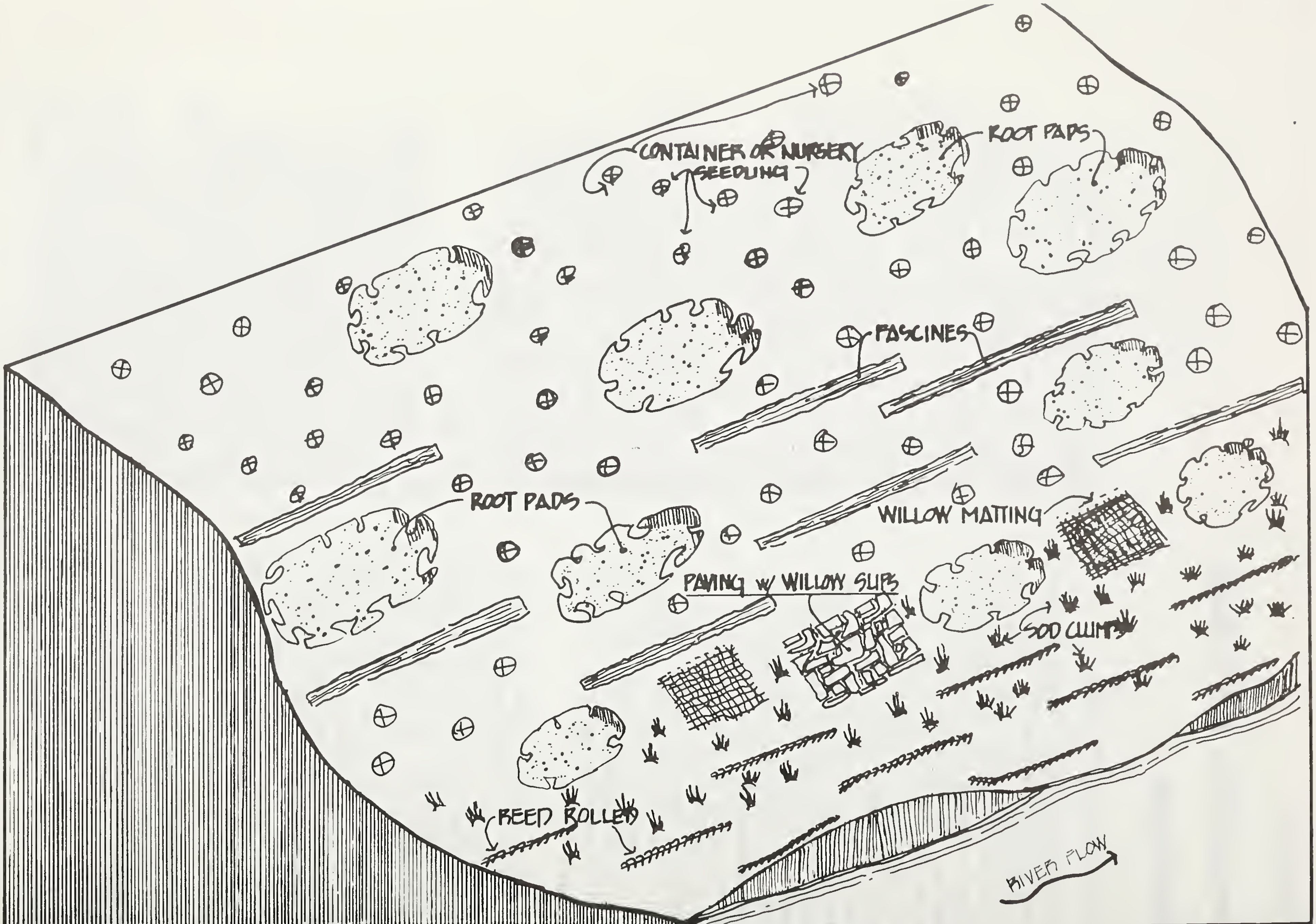


Figure 8: Planting Design for Streambanks

ing with willow slips between stones. Refer to the following section (pages 33-37) for a more detailed description of each supportive measure and Figure 8 for a conceptual planting design including these devices.

Gentler sloping sites on which wave action is not anticipated can have grasses direct seeded, but grasses established from seed require one to several months to develop erosion resistant stands. Therefore, supportive measures will be necessary on a greater percentage of the bank zone if seeding, rather than sodding is done. Stronger sloping sites like 1 vertical to 3 horizontal and 1 vertical to 1 horizontal sites must have an erosion control blanket or mat installed following mulching to reduce erosion. Similar treatments are suggested for more gentle slopes also. Woody plants can be transplanted onto protected sites with little disturbance to the mat or seedbed. However, direct seeding and mulching should follow transplanting of woody species where supportive measures are to be installed since the installation of these measures disturbs more of the plant area.

TERRACE ZONE

Generally the terrace zone should be revegetated using direct seeding and transplanting. The level terrace or graded slopes less than 1 vertical to 5 horizontal should require few vegetative structural measures to protect the areas from erosion. Small, one-year-old seedlings or container stock can be used in transplanting woody species on this site. Trees and shrubs should be systematically planted about 6 to 10 feet apart utilizing the complex of species recommended.

Sites with steep slopes, greater than 1 vertical to 3 horizontal, will need erosion control measures. Surface netting and mulching should be used to assure seedling establishment. Utilizing larger size transplants of woody species should be considered also. Supportive structures or sodding may be required in more severe situations such as 1 vertical to 1 horizontal slopes, heavy traffic areas, etc. Where surface drainage is causing gully erosion on the bank slopes a small furrow should be dug along the break of the terrace to divert or control the water.This ditch or furrow could be used to plant woody shrubs and trees, sodding of this trench may be necessary to prevent erosion.

PLANTING DATES

Direct seedings of herbaceous materials (i.e., grasses) made in late fall after October 15 are generally more successful and will be encouraged. Some grass competition will occur with shrubs and trees planted the same fall or the following spring, but it will not become a major limiting factor to shrub-tree survival and long-term growth. Revegetation schedules where woody species are planted more than 1 year after grass will be discouraged as a normal planting practice.

Plantings of native shrubs will generally be most successful when completed in the early spring before plant dormancy is broken. Nursery bare-root stock usually becomes available in mid-April (unless lifted from beds during the preceeding fall and kept dormant in cold storage) so planting can begin shortly afterwards. Snow, ice and mud will probably prevent earlier planting dates. Planting of woody species may extend to June 1, if planting stock is properly handled and if moisture conditions remain favorable on planting sites. When container stock material is used exclusively, the planting period can

extend throughout the summer months.

Although fall plantings of woody species are also effective, the inavailability of bare-root nursery stock during this period will limit any large-scale efforts. The excavation and placement of root pads and wildings may occur in the late summer or fall after plant dormancy has begun and when construction work associated with structural modifications of streambanks is in progress (i.e., machinery is most likely available to do root padding).

Table 5 gives a summary of planting date considerations for woody species as related to this project.

TABLE - 5 PLANTING DATES

1. Bare root nursery stock and dormant wildings.

   a. Spring-April 10-May 15 (approx)
   b. Fall-October 1-October 30 (approx)

2. Container grown

   a. Dormant stock handled as spring bare-root.

   b. Nondormant - after danger of severe frost has passed (May 21) until freeze up (October 30).

3. Root Pads and Wildings collected when in full or partial leaf.

   a. Preferably as dormant but some site specific species may require other times. August 15 to September 15 is recommended in order to allow time for some root growth before freeze up. This method is more time critical and care-critical than any other method and would require more supervision. It is recommended only where the other methods are not feasible.

DIRECT SEEDING OF HERBACEOUS SPECIES

Site preparation needed for seeding is minimal when topsoiling is practiced. Some tillage to reduce the compaction by heavy equipment used in topsoiling may be required. To prevent extensive mixing of subsoil materials with topsoil, tillage treatments should not extend deeper than the topsoil bottom.

Optimum establishment of seeded grasses in a droughty environment requires the placing of seed beneath the soil surface so that good seed-soil moisture contact is made during the germination stage. Therefore, it is desirable on all 1 vertical to 8 horizontal and 1 vertical to 3 horizontal slopes and on terrace areas to seed by drilling where practical or to use special equipment to get proper seed placement in the soil surface. Generally, seed will be sown at an approximate depth of 3/4 to 1 1/4 inches in the sandy loam soils typical of the treatment area.

Hydroseeding can be an effective method of broadcast seeding on the steeper 1 vertical to 1 horizontal slopes or possibly the entire area. Areas to be hydroseeded must first be lightly harrowed to incorporate the broadcasted seed and to help grass become established. Mulches will be applied following the seeding to reduce soil moisture loss and to tie down and cover seeds and reduce immediate surface soil erosion by wind and water.

The source of seed must be considered when purchasing seed. Tame grasses like reed canarygrass, creeping foxtail and Kentucky bluegrass and the legumes can be obtained from sources

where available; however, seed of natively adapted species like western wheatgrass, little bluestem and big bluestem should be obtained preferably within a 200 mile radius of the planting site. Seed lots selected will be approved by the Corps of Engineers. Noxious weeds will not be a part of the seed lot.

Suggested seed mixtures and seeding rates for the bank and terrace zones are shown in Table 6. Seeding rates are based on approximately 100 seeds/ft^2 of pure live seed (PLS). Pure live seed concept assumes that each pure live seed is capable of producing a viable plant if given proper environmental conditions. Pure live seed is calculated by the following formula:

$$\% \text{ PLS} = \frac{(\% \text{ germination}) \times (\% \text{ purity})}{100}$$

If the PLS of a seed lot is less than 95 percent, the seed quantity used to compound the suggested species mixture should be adjusted upwards by dividing the suggested rate by the PLS. For example, if reed canarygrass seed lot has a 80 percent germination and a 95 percent purity, the PSL would be 76 percent (80 x 95 ÷ 100) and the seed quantity used in the seed mix for the bank zone would be about 4 pounds. The seeding rate/acre of the mixture is increased proportionally to the increase caused by the PLS adjustment. Number of seeds per pound and recommended seeding rate for individual species of selected grasses and legumes are given in Table 7.

Table 6 Recommended seed mixture and seeding rate for bank and terrace zones.

Bank Zone

Species	Seed PLS lbs/acre	Minimum Germination 1/
Reed canary grass	3	80%
Creeping foxtail	2.5	85%
Crownvetch	2	90%
Sweetclover	2-3	90%
	9.5-10.5 lbs/acre	

Terrace Zone

Species	Seed PLS lbs/acre	Minimum Germination *
Reed canary grass	2	80%
Creeping foxtail	1	85%
Western wheatgrass	2	80%
Little bluestem	2	50%
Big bluestem	2	50%
Switch grass	1	80%
Kentucky bluegrass	1	85%
Sweet clover	1-2	90%
	12-13 lbs/acre	

1/ Seeds with germination rates less than the minimum germination rates should not be used.

MULCHING

Mulch is essential to protect seed and soil from eroding off sloped banks, particularly on the upper, steeper portions.

Straw or clean grass hay should be applied uniformly over the banks at a rate of 3,000 pounds per acre through the use of "Finn" type mulch spreaders. Hay and straw material will be free of mold, fungus or weed seed. Lincoln Oakes Nursery of Bismarck has agreed to make available some surplus grass hay for this purpose. The hay contains a seed component of several of the grass species chosen for this project which may provide an additional benefit.

Woven mesh or net-type mulches are generally effective and should be considered a viable option on steeper bank slopes. The 3 to 4 foot wide rolls can be attached to these areas by healing the net top into the soil and by using fabricated staples placed at specified intervals. The combination of "Jute" type net and straw is effective in arid areas.

Artifical fiber-type mulches should be discouraged since they are usually ineffective in most situations except where irrigation is provided.

SOD PLANTING

Sod planting is a practice in which sections of grass or herbaceous plants are lifted from existing beds and transplanted to the disturbed sites. Small sections or plugs 2-4 inches in width and 4-6 inches in length can be dug and lifted from wild-land sites or nursery or greenhouse grown. Many species are well adapted to this method of planting. The plugs are placed in pits at a depth which allows the aerial organs of the plant to be exposed. (Figure 9)

Large rolls of sod can also be lifted and field planted on areas where surface stability is most critical. Stakes will be used to assist in securing the sod to the slope until the plants become rooted. Sections of sod can be dug or lifted from native plant communities using large diggers, frontend loaders, backhoes, etc. The sod or root mass is then transferred to the planting site and planted.

REED ROLLS

Reed rolls are constructed by grouping and planting transplant section of sod, rhizomes and shoots. Various species can be planted in this manner. Slips are taken from existing beds during the inactive season. Rhizomes and shoots are removed and pruned to insure the use of healthy material. A trench approximately 16 inches in width is dug into the bank; wire netting is stretched across the trench; coarse gravel, sods or the reed-clumps are placed in the net; the wire is then drawn around the material and tied with wire. A row of stakes are placed below the roll and attached to the wire to provide stability. For further directions, refer to Seibert, 1968 (12) and Figure 10.

SPRIGGING

Sprigging (see Figure 11) is applicable in wet and moderately wet zones, using the suitable species shown in Tables 2 and 3. All species should be planted at a rate of approximately 40 sprigging bushels per acre. Aerial organs of plant colonies such as reeds or grasses are scythed, and then rhizomes and shoots are carefully removed from the soil. They are placed in holes or narrow trenches, so that only the aerial sprouts are above the soil. (Seibert 1968). (12)

Table 7 Number of seeds per pounds and seeding rates for grasses and legumes recommended for revegetation.

SPECIES		Seed/lb	lb/Acre
Grasses			
Giant mannagrass	Glyceria grandis	NI	NI
American mannagrass	Glyceria striata	NI	NI
Reed canary grass	Phalaris arundinacea	524,670	6-11
Creeping foxtail	Alopecurus arundinaceus	NI	NI
Northern reed grass	Calamagrostis inexpansa	NI	NI
Prairie cordgrass	Spartina pectinata	NI	NI
Quack grass	Agropyron repens	242,550	7-13
Western wheatgrass	Agropyron smithii	NI	NI
Crested wheatgrass	Agropyron desertorum and Agropyron cristatum	172,265	6-12
Intermediate wheatgrass	Agropyron intermedium	86,265	8-12
Streambank wheatgrass	Agropyron riparium	153,562	6-12
Redtop	Agrostis stotonifera	4,192,031	5-10
Little bluestem	Andropogon scoparius	133,875	10-20
Big bluestem	Andropogon gerardi	162,422	11-15
Switch grass	Panicum virgatum	382,922	5-8
Smoothbrome	Bromus inermis	108,281	5-15
Kentucky bluegrass	Poa pratensis	2,142,984	15-25
Legumes			
Crownvetch	Coronilla varia	108,281	15-20
White sweetclover	Melilotus albus	255,455	10-15
Yellow sweetclover	Melilotus officinalis	255,938	10-15

N I = No information

FASCINES AND WATTLES

Fascines are lengths of switches or stems of willow or other sprouting species packed together in a tight continuous roll 10 to 60 feet in length and 4 to 5 inches in diameter. They are buried across a slope at regular contour intervals and are supported on the downhill side by stakes set at right angles to the slope (see Figures 10 and 12). When applied to slopes, fascines provide an effective deterent to downhill surface movement of soil caused by downward water flow, wind action, trampling of wildlife and livestock and the forces of gravity. In addition, sticks of such species as willow used in the fascine have the ability to sucker and set roots which can help stabilize the soil.

Fascines will be built from 2 to 3 year old willow switches or switches from similar species, 4 to 6 feet long and held together in a tight roll by wire. Stakes will be at least 30 to 36 inches in length, 1" x 1" in thickness and spaced at 15 to 18 inch intervals. For steeper slopes, every fourth or fifth stake driven will be 40 to 48 inches in length and 2" x 2" in thickness. The entire roll will be attached to the stakes with galvanized wire before the stakes are pounded to a depth where only 3 inches protrudes from the ground, or where the fascine is held firmly in place. Fascines can also be held in place by living willow cuttings called "wattles" which are used in place of some of the stakes.

Numerous rows of fascines should be set at 3 to 4 foot intervals. Each fascine will be lightly covered with earth so that branches are only partially covered up. In this manner, sprouting will be encouraged.

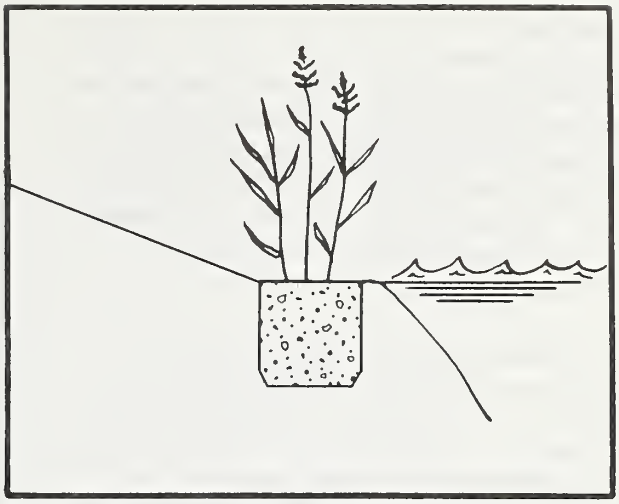


Figure 9: Sod Placed in a Pit [12]

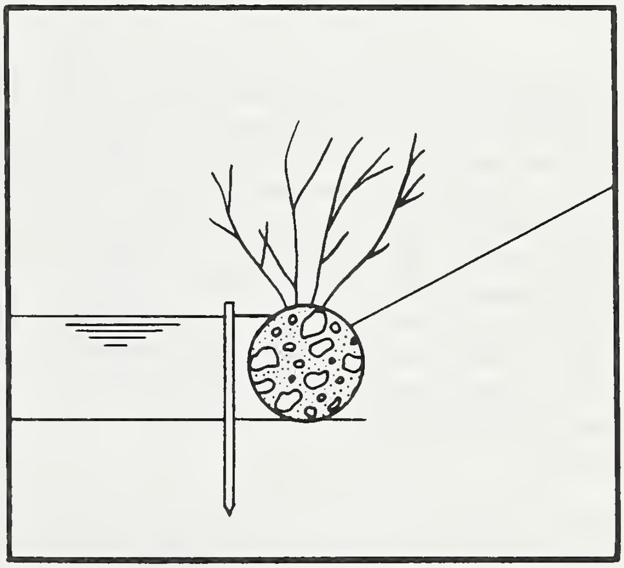


Figure 10: Planting of Reed Roll [12]

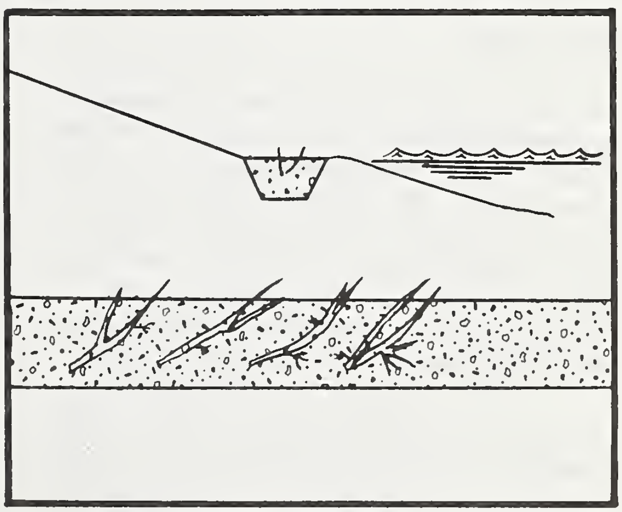


Figure 11: Sprigging [12]

BARRIERS

Barriers, made by interlacing willow shoots, are used in areas where stream erosion may uproot small transplant stock. Seibert, 1968 (12) provides the following guides in the construction and use of willow barriers:

"The barriers are made of willow switches 2 to 3 years old and 4-3/4 - 6-1/4 feet long which are placed at intervals 0.4-0.6 inches, perpendicular to the current or sloping downward. They are set in a trench 6 inches deep, which is filled in afterwards."

"The spread willow switches are held in place by wire, by fascines or by willow hurdling. Before the switches are set out, the stakes, 1-7/8 - 3-1/4 feet long, needed for the wire and for fixing the large hurdles to the ground, are driven in so that 4-8 inches are still showing. After setting up the switches, the stakes are wired together with galvanized wire, then again driven home until the switches are firmly held to the ground---."

"The whole barrier is lightly covered with earth; so that the branches are set in earth but not completely covered up."

ROOT PADS

Large clumps of shrubbery commonly referred to as "root pads" will be used on a supplemental basis, where practical, in splash, bank and terrace zones of the bank. Clumps of species such as willow, red osier dogwood, cottonwood, rose, hawthorne and silver buffaloberry are well suited for this purpose.

Front-end loaders or "Veimeer" type spades are well suited for the excavation and placement of root pads. Placement on slopes greater than 1 vertical to 6 horizontal should

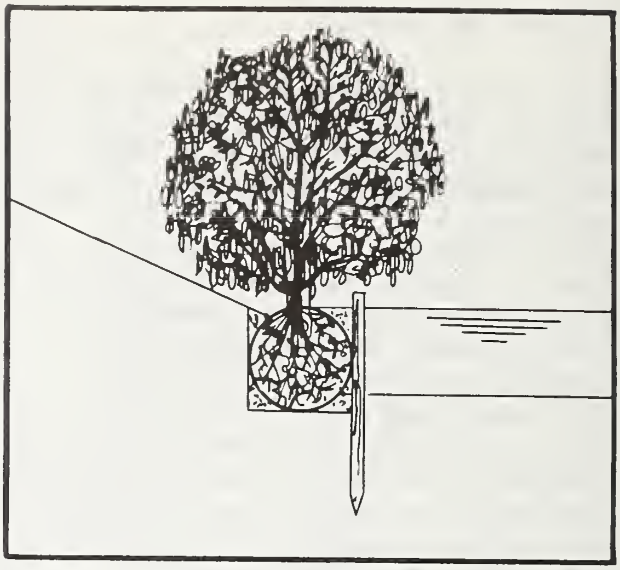


Figure 12: Fascines [12]

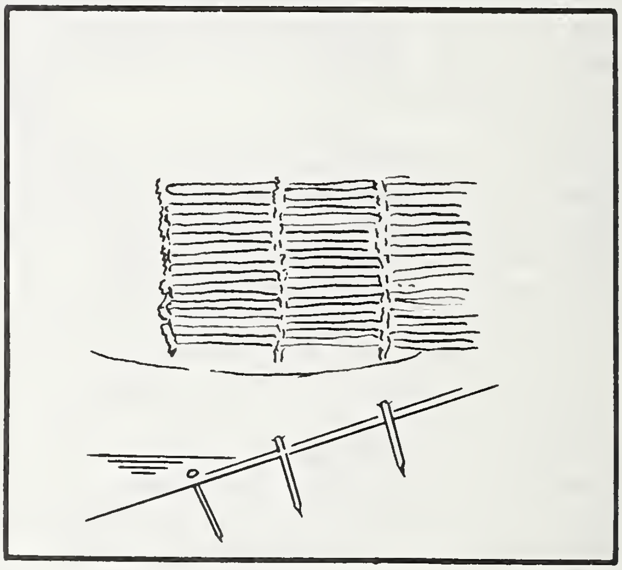


Figure 13: Willow Barriers [12]

include securing the root pads by driving 2 inch diameter, 18 to 24 inch long wooden stakes through the pads at 2 to 3 foot intervals. Potential source areas of root pads include the following:

(1) construction sites where pads of vegetation can be removed and stored for future use, (2) where private landowners will allow removal of pads from adjacent sites, assuming no permanent degradation will occur to those lands, and (3) nearby lands owned by the Corps of Engineers and managed by the North Dakota Department of Fish and Game.

FERTILIZATION

Fertilization of herbaceous species can be incorporated into the hydroseeding slurry application (seed, water and fertilizer) applied in the late fall. When using fertilizers in a hydro-seed slurry, initial application rates should not exceed 15 lbs. of actual Nitrogen (N) per acre. This low rate will prevent the excessive concentration of salts in the slurry solution which is damaging to grass seeds.

Additional follow up applications of fertilizer on the treatment sites will be made for the first few years after seeding in order to encourage establishment and promote a heavier grass cover. Such applications can be made in the late fall or early spring at a rate of 40-50 lbs. of actual N per acre. Maintenance fertilization treatments at similar rates will probably be necessary every 3-5 years. The use of high phosphate fertilizers are encouraged.

Initial treatment of individual woody plants by using fertilizer "starter" tablets are generally effective and should be used. One 9-gram tablet per plant is considered adequate. Tablet fertilizer formulations that are low in N and high in phosphate are more desirable because they tend to promote greater root growth and less top growth during the first few years of establishment. This is important for plant survival and for holding soil in place.

Eight:

Plant Procurement and Costs of Woody Species

PLANT PROCUREMENT

Commercial availability of the plants discussed as being native or suitable for the areas under discussion have been listed on pages 23-25 . Many of the species are not readily available without special emphasis. Attention must be paid to seed sources in order to have winter hardy material (genetically adapted to site). A partial listing of suitable nurseries is in the appendix. More detailed lists are available from the North Dakota State University plant source book or Association of American Nurseries, 230 Southern Building, Washington DC.

Special propagation of selected plant material is necessary, since many of the site specific species are not readily available from commercial sources. Plans for plant procurement must be made as soon as possible in order to be sure of a source. Nurseries need lead time. The nursery selected or contracted to grow the material must either collect seed from suitable plants in the wild (and not every year is a seed year) or collect plants from the wild and grow them under controlled conditions until the planting season. Container grown material from a greenhouse is another alternative to nursery grown bare-root material or wildings and should not be overlooked when contracting for the plant material. Native plants are not as common in the trade because of the difficulty in growing them. The idea of phase planting must be considered in order to give the areas a mixture of plants. This means planting as soon as possible, either during or following construction as soon as some plant material is available and coming back with additional species (and perhaps replants, if needed) as they become available. In the zone most subject to inundation, consideration should be given to a larger grade of plant material (up to 4'). The other material should follow the size specification recommended in the "Tree Planting Handbook for the Dakotas" (30).

PLANT HANDLING

Many mechanical contractors do not understand the necessity of careful attention to the details involved in the care and handling of live plant material and the scheduling of the necessary steps. Close communication betweem the nursery, the transportation system used by the contractor, the planting personnel, the contractor himself and the contract administrators and inspectors is necessary to insure that live plant material in optimum condition is placed in properly prepared sites. Plant handling varies with the contractor and type of material, i.e., refrigerated vans on site for the entire planting job to twice daily pick up at the nursery in enclosed carriers. Care of material also varies greatly because of the species, whether bare-root or container grown. There is a difference between container grown and containerized.

Consideration should be given to various alternatives in the process of "who does what."

A contract for the entire project including revetment work, planting stock procurement, and installation, or:

A contract for revetment and installation with a separate plant procure-

ment contract or:

Separate contracts for all three phases of the project. Maintenance of the planting should be considered to insure establishment. Chemicals are probably too environmentally hazardous to use. Hand noxious weed control will be expensive but may be occasionally necessary. Planting more seedlings per acre may be the most practical, thereby letting natural selection occur.

Plant losses can come from animal damage, ice damage, inundation, as well as competition or failure of the seedling to grow. Close communication between the grower or supplier of planting material and the Corps is critical due to replanting needs, changes in methods or species, construction delays or planting stock problems at the nursery.

ESTIMATED STOCK COSTS (see Table 8)

The variation in price is subject to plant numbers desired, availability of species, seed, method of propagation, nursery overhead, etc. A cost of planting stock can be estimated when species, numbers, etc. are selected for a specific site.

Transportation costs are usually figured at 20 percent of cost of plant material. Planting stock costs for bare-root nurseries (Government) range from $26/M to $80/M for mostly coniferous species. Container costs range from $40/M to $500/M depending on the location of the facility, size of container, amount of time in the container and the species.

Planting costs for bare-root range from the basic 5 cents per plant upwards to 15 cents.

Container planting costs for hand planting range from ½ the cost of bare-root seedlings to costs equal to or exceeding the cost of the container seedling. Two hundred to 400 plants per person day can usually be planted.

Table 8 ESTIMATED PLANTING STOCK COSTS FROM VARIOUS SOURCES 1/

Type of Plant Material	SOURCES Government	Private	Wilding	Contract
	- - - - - - - Cost per plant			- - - - - - -
Bare-Root 15" - 24" Min. Size	$0.08-$0.18	$0.10-$0.36	$1.00-$1.50	$0.08-$1.50
Container Grown 2" x 2" x 8"	$0.40-$0.50	$0.50-$1.50	N/A	$0.50-$1.50
Larger Container	N/A	$1.50-$7.50	N/A	$1.50-$7.50

1/ These are estimated based on averages.

Nine:

Monitoring and Evaluation

DIRECT DOCUMENTATION OF EROSION PROTECTION

AERIAL PHOTOGRAPHIC MONITORING

Each engineering structure (i.e., revetment, hard point, etc.) should be monitored for erosion directly by use of aerial photogrammetric techniques. This will allow evaluation of changes occuring at the land water interface providing the procedures discussed below are used.

Aerial photo coverage must be flown at least twice a year. Suggested times are in the spring and in the fall. Photo flights should be highly controlled; that is, the scale of repeated flights must be the same. To allow comparisons of repeated photo coverage, flights must be made during low water periods and when river water levels correspond to each other. Overlays can be made on the photos which will delineate the water-interface boundary. Subsequent overlays can be compared showing any changes in the water-interface boundary (see Figure 14). Photogrammetric measurements can then be made on the overlays to determine amount of surface area lost to erosion.

GROUND PHOTOGRAPHIC COVERAGE

The above aerial photo coverage should be supplemented by ground photos taken at established photo points with photos taken periodically for a given azimuth. These must be taken at the same time the aerial photos are taken; however, others can be taken at intermittent times if deemed necessary.

OCULAR DESCRIPTION

As a further effort to document erosion, a description of any erosive processes must be made at the same time the ground photos are made. Processes that must be documented and particularly noted include such things as slumping, rilling, gullying, wind erosion and wave action. Descriptive estimates of degree of severity for each of the above processes per engineering structure will be made.

INDIRECT DOCUMENTATION OF EROSION PROTECTION

Erosion protection is assumed to be offered by the vegetation if the plants are surviving and developing; that is, covering the site. The development of the vegetation needs to be monitored and possibly correlated, at least from a visual standpoint to the degree of erosion or lack of erosion taking place on the treated streambank. One would assume, for example, that vegetative plantings are doing a good job if the vegetation is growing well in all elevation zones on the revetment structure and aerial/ground reconnaissance indicate no erosion is taking place.

WOODY PLANT SURVIVAL AND VIGOR

Woody seedlings (rooted transplants) will be monitored for survival and vigor in each elevation zone on the treated streambank. After planting, 10 percent of the woody seedlings in each elevation zone will be systematically selected and marked with a stake. Each marked plant will be revisited periodically to determine whether it is alive or dead and observe its vigor of growth. Percent

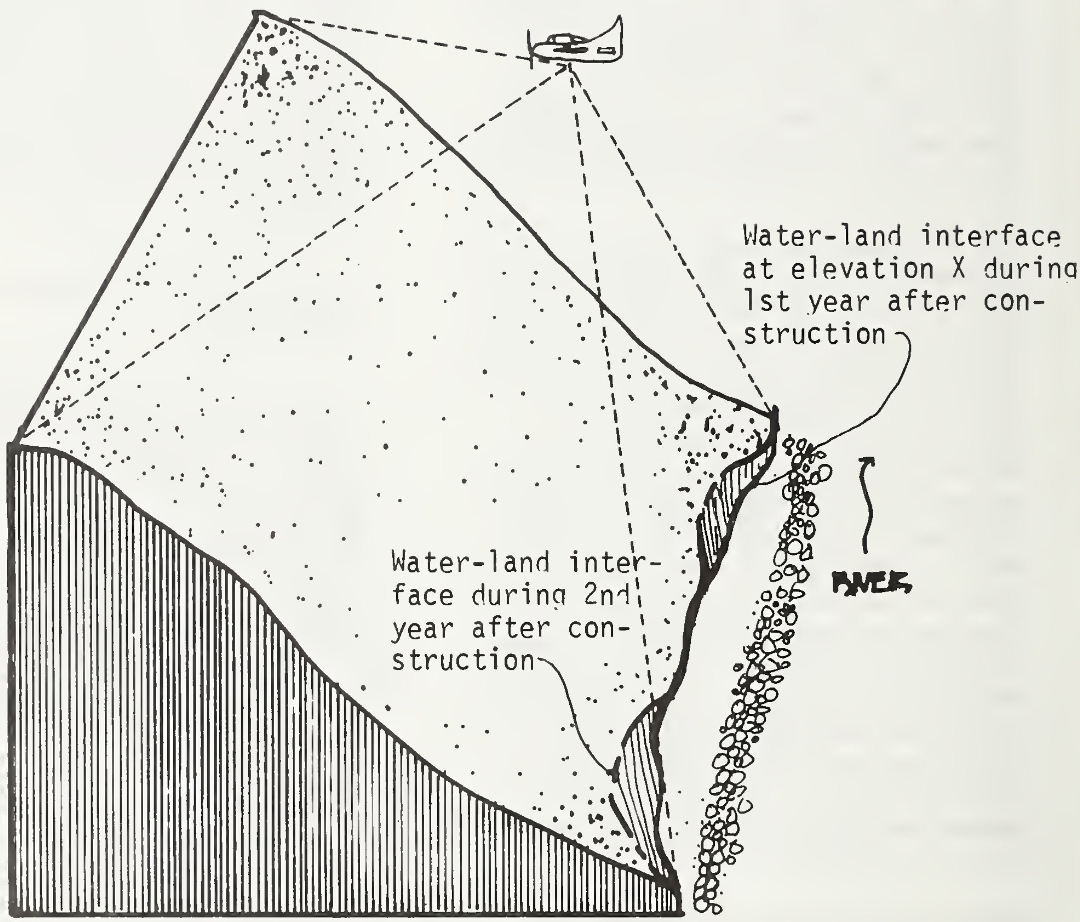


Figure 14: Aerial Monitoring

survival can be determined by dividing the number alive by the original number staked. Vigor can be determined subjectively by assigning each live plant a vigor class which is shown below:

a. Plant growing vigorously (new growth, green stem and leaves, no yellowing of leaves) - Class 3.

b. Plant is growing, but stable (no new growth, just green) - Class 2.

c. Plant is declining in vigor (stem deteriorating, leaves dropping, yellowing of leaves) - Class 1.

The frequency of monitoring plant survival must be a minimum of once a growing season (probably near the end of summer) for three consecutive years. Preferably monitoring will be done at a frequency of twice a growing season (once in the spring and once near the end of summer) for 3 years.

GROUND COVER AND STEM DENSITIES

A measurement of ground cover is periodically needed to determine if the herbs, particularly, are spreading successfully across the site. Measurements of stem densities are needed to determine if woody cuttings and fascines are sprouting and adding to the vegetative composition and density. Both of these factors can be measured by establishing 1 square meter plots randomly throughout each elevation zone until a 1 percent sample is achieved. These plots must be permanently established immediately after planting and delineated by well-marked stakes.

Ground cover for each plot will be determined by using ocular estimates divided into cover classes as described below. Each cover class will be assigned a number and recorded on the data sheet for that plot. Only live vegetation will be considered and the individual must rely on his visual estimation.

CATEGORY DESCRIPTION (% Live Cover)	NUMBER OF CLASS
1	1
1-9	2
10-24	3
25-49	4
50-74	5
75-100	6

Once percent ground cover has been determined for each plot, composition by dominant species will be estimated. A list of the dominant plant species for each plot will be prepared.

Stem densities of woody plants must be determined by species for each plot by counting the number of stems. This will give an estimate of number of stems per species per square meter.

The recommended frequency of monitoring for ground cover and stem densities is the same as that described for woody plant survival and vigor.

WATER LEVEL MONITORING AND DOCUMENTATION OF FLOODING

It is highly recommended that water levels be monitored by continuous recording gages since the success of the vegetative plantings is dependent upon the degree of flooding.

PROPOSED PROCEDURE

It is suggested that three Fischer-Porter continuous recording water level gages be placed on the 80-mile reach of river between Garrison Dam and Bismarck. One gage will be placed on the upper reach, one in the middle reach, and one on the lower reach. Gages have the capability of continuous recording for 1 month before the tapes and batteries must be

changed. The U.S. Army Engineer Waterways Experiment Station (WES) has the capability of taking the output from such recorder-gages and inputting its tape into a water level reader which converts the water level data into computer input on keypunched cards. Output is in the form of bargraph charts showing percent duration of inundation based upon any designated time increment.

Water level monitoring in conjunction with the monitoring of plant survival and performance gives a better capability of determining if plants were impacted upon by frequency and durations of flooding.

It is believed the above direct (aerial/ground reconnaissance) and indirect (plant survival and performance) methods of documenting and evaluating the success of the plantings will, in concert, give a good evaluation procedure.

SPECIAL MONITORING

The procedures for monitoring already documented will give a quasi-quantitive way of determining success or failure of each site receiving vegetative treatment. However, these procedures do not provide the means of quantitatively (statistically) determining which plant species will perform best in such situations nor do they provide the means of determining which planting technique (i.e., supported vs. unsupported vegetation) provides the most rapid plant cover for the least cost.

It is therefore recommended that the Omaha District consider an additional option of allocating part of a revetment (preferably 500-600 linear feet) for an experimental planting and monitoring effort which is conducive to a statistical analysis. Such an experiment would allow probability statements to be made about performance of certain plant species versus others and about certain planting techniques versus others.

In general, it is envisioned that the experimental designs of the field plots will be tested in four parts of of the revetments. One revetment will be used as a control. Three other revetments will have three plots each delineated by elevation zone. Field plots would be arranged in a way to allow a statistical analysis of which plant species in each elevation zone performs well and of what planting treatment gives the best results.

If the above option is given serious consideration by the Omaha District, a more detailed plan of study with experimental design will be presented at a later date.

Appendix

Partial Listing of Nurseries

Possible nursery sources for planting stock needed for Missouri River bank stabilization include the following:

North Dakota State Forest Service Nursery
Towner, ND

J&N Nursery
Sheldon, ND

Lincoln-Oakes Nurseries
Bismarck, ND

Clarkdale Nurseries
Milbank, SD

Gurney's Seed & Nursery
Yankton, SD

Big Sioux Nursery
Watertown, SD

Lee Nurseries
Fertile, MN

Lawyer Nursery
Plains, MT

Bailey Nurseries
Saint Paul, MN

Smith Nursery
Charles City, IA

Plumfield Nursery
Fremont, NB

Colorado Forest Service
Fort Collins, CO

Native Plants
Salt Lake City, UT

Montana Division of Forestry
Missoula, MT

Kester's Wildgame Nurseries, Inc.
Omro, Wisconsin

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Biographries

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Mr. Allen has been employed for the last 10 years as a research ecologist with the U.S. Army Engineer Waterways Experiment Station at Vicksburg, Mississippi. Mr. Allen's experience has been responsible for individual test programs or portions of major studies to establish the impact of natural and man-induced activities on the environment and to determine means of making those activities more compatible with environmental amenities. Specific areas of interest have included studies directed toward vegetating dredged material and developing wildlife habitat on the same and vegetating denuded drawdown zones of reservoirs.

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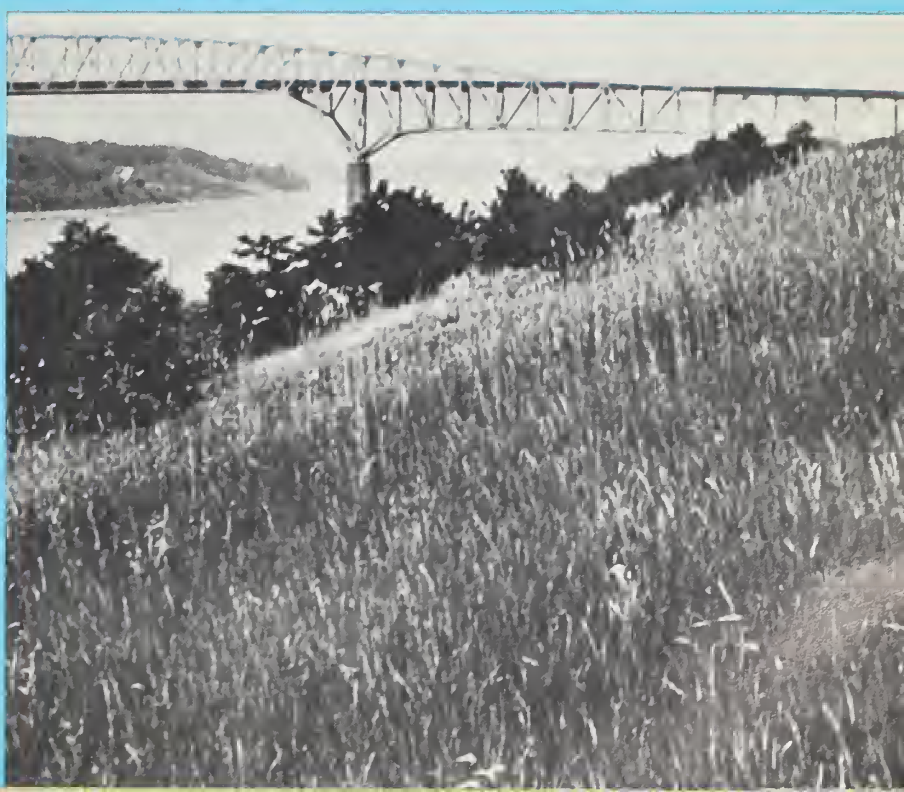
CRREL REPORT 83-28

US Army Corps of Engineers

Cold Regions Research & Engineering Laboratory

Long-term plant persistence and restoration of acidic dredge soils with sewage sludge and lime



For conversion of SI metric units to U.S./British customary units of measurement consult ASTM Standard E380, Metric Practice Guide, *published by the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.*

Cover: Photo at left shows an eroded embankment along the Chesapeake and Delaware Canal. The embankments were subsequently seeded and treated with limestone, fertilizer and topsoil in September 1974. Photo at right is the same site in May 1976.

CRREL Report 83-28

December 1983

Long-term plant persistence and restoration of acidic dredge soils with sewage sludge and lime

Antonio J. Palazzo

Prepared for
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
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A field study was conducted to determine whether sewage sludge and lime could be useful as soil amendments on acidic (pH 2.4) and infertile dredged spoils and to evaluate grasses that may be suitable for restoring acidic dredged spoils. Applications of dolomitic limestone in combination with sewage sludge or commercial fertilizer and topsoil improved soil fertility and produced a better overall growth environment at the site. Metal concentrations resulting from sludge applications increased but not to excessive levels. Movement of metals below the 20-cm depth was noted for the extractible forms of zinc, copper and nickel. A total of 29 grass treatments, containing grasses seeded alone or in combinations and receiving the sludge/lime treatment, were evaluated over a seven-year period, and selected grasses were analyzed for mineral composition. All grass species showed good establishment on the amended, acidic spoil. The ryegrasses

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(*Lolium multiflorum* L. and *Lolium perenne* L.) were quickest, followed by K-31 tall fescue (*Festuca arundinacea* Schreb.), the red fescues (*Festuca rubra* L.), bentgrasses (*Agrostis tenuis* Sibth. and *Agrostis palustris* Huds.) and Kentucky bluegrasses (*Poa pratensis* L.). The ryegrasses and bentgrasses began to deteriorate 21 months after seeding and were not noticed on the site after 50 months. Grasses sown in mixtures with annual ryegrass were not as vigorous as those sown without it after 21 months, mainly due to the earlier aggressive growth and eventual lodging of annual ryegrass. Slight reductions in the ratings of K-31 tall fescue were also noted at this time and were partially related to lodging. This species had higher ratings in subsequent evaluations. Although establishing slowly, the Kentucky bluegrasses had high ratings after 21 months and through the remainder of the study. The red fescues performed well up to 50 months after seeding, but then declined. After 82 months the most persistent species were the Kentucky bluegrasses, K-31 tall fescue and the red fescues. Most treatments in this study had good soil cover after 82 months. As the study progressed, other species were able to dominate sites where less persistent species were sown. There were no continuing differences between varieties within species. The only difference in the chemical composition of selected plants sampled 50 months after seeding was the high concentrations of zinc in Pennlawn red fescue and phosphorus in K-31 tall fescue. After this time the red fescues received lower visual ratings, indicating a partial metal toxicity.

PREFACE

This report was prepared by Antonio J. Palazzo, Research Agronomist, Earth Sciences Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory. This research was originally funded by the Philadelphia District of the Corps of Engineers, with subsequent observations and revisions conducted under CWIS 31013, *Vegetation Restoration on Construction Sites in Cold Regions.* The author appreciates the technical support provided by J. Lakatosh, W. Mueller and J. Radley of the Philadelphia District of the Corps of Engineers and J.M. Graham of CRREL. The Lofts Pedigreed Seed Co. and O.M. Scotts Seed Co. supplied seed for this study. The author also expresses his appreciation to C.E. Clapp, U.S. Department of Agriculture-Agricultural Research Service; R. Hurley, Lofts Seed Co.; C.R. Skogley, University of Rhode Island; and Barbara Gartner of CRREL for reviewing this report.

LONG-TERM PLANT PERSISTENCE AND RESTORATION OF ACIDIC DREDGE SOILS WITH SEWAGE SLUDGE AND LIME

Antonio J. Palazzo

INTRODUCTION

Information on grass growth for long-term restoration of acidic dredge disposal areas and other disturbed lands is needed for developing strategies for establishing and managing vegetation. Restoring dredge disposal areas that contain pyritic soils is difficult because of their low pH, low organic matter content and general infertility (Fleming et al. 1974, Edgerton et al. 1975, Stuckey et al. 1980). In general, pyritic soils become highly acidic when brought in contact with the atmosphere (Jefferies 1981). Plants usually become established easier if the pH of the soil is raised and soil amendments are mixed into the soil to improve conditions for plant growth and to allow for deep root penetration (MacLean and Dekker 1976, Pinkerton and Simpson 1977, Sorenson et al. 1980, Stuckey and Zoeller 1980).

The use of sewage sludge to reclaim acidic dredge spoils may improve plant growing conditions by rapidly increasing the organic matter, fertility and pH of the soil (Cunningham et al. 1975, Palazzo 1977, Sutton 1979, Stuckey et al. 1980), but it also can add potentially toxic metals. Additions of lime will decrease the availability of metals in acidic soils (Palazzo and Duell 1974, Murray and Foy 1978, Stuckey et al. 1980), but large quantities of lime may be needed to reduce the acidity of pyritic soils (Sorenson et al. 1980). By adding lime and sludge together, it may be feasible to improve soil fertility to a level at which certain grasses can persist, thereby stabilizing the soil.

A potential problem in applying sewage sludge containing metals to low-pH soils is toxicity to plants. In acidic soils, metals are both more available to plants and more susceptible to leaching. Copper, zinc and nickel appear to be the metals most likely to become toxic to plants when sewage sludge is applied to land (Webber 1972).

Chaney (1974) recommended that soils receiving sewage sludge be adjusted to and maintained at pH 6.5 or higher. Monitoring sites is important, since the soil pH can decrease after many applications of sewage sludge (Lunt 1959, Hinesly et al. 1971, Sutton 1979). Plants generally grow best in soils with a pH near 6.5. The tolerance of various grass species to low-pH soils has been reported by Spurway (1941), Musser (1962), Beard (1973), Palazzo and Duell (1974), and Murray and Foy (1978).

The objectives of this long-term study were 1) to determine whether applications of sewage sludge and dolomitic limestone could be useful as soil amendments and 2) to evaluate different grasses that may be suitable for restoring highly acidic dredged spoils. To be suitable the grasses must be able to survive and to stabilize soils, they must tolerate the toxic materials that may be in the sewage sludge or dredged material, and they must be able to persist with little management.

MATERIALS AND METHODS

Soil amendment plots

The dredge spoil discussed in this study was located along the Chesapeake and Delaware Canal in Delaware near Chesapeake City, Maryland. The experimental site was on the south side of the canal near the Summit Bridge. The spoil consisted

Table 1. Composition of Wilmington sludge applied in July 1974.

	Sludge composition (dry weight)	
Element	*Mean*	*Range*
Total N (%)	2.6	
Total P (%)	5.4	
Total K (%)	0.25	
Cr (μg/g)	9,584	5,560–12,890
Cu (μg/g)	2,772	1,290–4,654
Zn (μg/g)	3,470	2,186–4,230
Pb (μg/g)	1,327	724–2,520
Ni (μg/g)	227	140–311
Co (μg/g)	15.7	9.2–20.3
Cd (μg/g)	27.3	9.2–49.4

of acidic dredged disposal material that varied widely but was predominately a silt loam in texture. Three areas were studied: one treated with sludge and lime (sludge treatment); one treated with commercial fertilizer, topsoil and lime (fertilizer treatment); and one that did not receive any treatment (control).

Within the 6.6-ha sludge-treated area, sewage sludge and dolomitic limestone were applied during July and August 1974. Anaerobically digested primary sludge from Wilmington, Delaware, was initially placed on a sand filter drying bed. After drying, the sludge contained 21.5% solids. The sludge was trucked to the site and spread as uniformly as possible over the soil surface at a rate of 100 metric tons/ha on a dry weight basis. The average chemical composition of the sludge applied in July 1974 is shown in Table 1. The highest value for lead at Wilmington was above that noted in a review by Page (1974), while lead, chromium, copper and zinc were higher than those reported by Peterson et al. (1973). The high concentration of metals in the sludge indicates that industrial input was appreciable. After the sludge was applied, dolomitic limestone was broadcast at a rate of 23 metric tons/ha and was plowed to a depth of 20 cm.

The 20-ha fertilized area received applications of 13.8 metric tons/ha of dolomitic limestone and 550 kg/ha of 0–20–20 fertilizer and was tilled to a depth of 10 cm. We then applied 10 cm of topsoil to the site, which was tilled to a depth of 15 cm, intermixing the topsoil with the existing dredge spoil. Another 6.9 metric tons/ha of dolomitic limestone and 1320 kg/ha of 10–6–4 fertilizer were next applied to the site and tilled to a depth of 5 cm. The only application of fertilizer after seeding was 660 kg/ha of 10–10–10 fertilizer applied to both sites in the fall of 1979.

Soils were sampled in November 1978 at three locations within the sludge-treated, fertilizer-treated and control areas at depth of 0–20, 20–40 and 40–60 cm. Samples were dried at room temperature (below 25 °C) in a drying cabinet and then crushed and passed through a 2-mm stainless steel sieve. Soil pH was determined at a 1:1 soil-water ratio, conductivity was determined at a 1:2 soil-water ratio, and organic carbon was determined by the Schollenberger method (Black 1965).

The atomic absorption spectrophotometer was used to analyze exchangeable and water-soluble calcium and magnesium; exchangeable and soluble magnesium and potassium were determined colorimetrically (Flannery and Markus 1971). Total metal and phosphorus were determined by boiling 2 g of soil for 2 hours with 15 ml of 70% $HClO_4$; phosphorus was then determined colorimetrically and metals by atomic absorption spectrophotometry (Black 1965, Motto et al. 1970). Extractible metals were extracted by the DTPA procedure of Lindsay and Norwell (1978) and determined by atomic absorption spectrophotometry.

In September 1974 the sludge and fertilized sites were seeded with a drill seeder. The seed mixture and percentage by weight of each grass was: K-31 tall fescue (*Festuca arundinacea* Schreb.), 50%; Pennlawn red fescue (*Festuca rubra* L.), 40%; weeping lovegrass (*Eragrostis curvula* L.), 5%; and redtop (*Agrostis alba* L.), 5%. The seeding rate was 132 kg/ha. Hay mulch was applied at 2200 kg/ha.

Plant yields were taken from three 9-m² subplots in the sludge and fertilized areas in October 1978. The plants were cut at a height of 10 cm with a sickle bar mower and dried to constant weight.

Species evaluation plots

Within the sludge-treated area, a 500-m² site was used to evaluate grass species. This site was set up as a complete randomized block design and contained 87 individual plots with an area of 5.76 m² each. Eighteen grass species and varieties were sown alone or in combination (Table 2). The seeding rates and composition of each mixture are shown in Table 3. There were three replications of each of the 29 treatments.

In May 1975, May 1976, October 1978 and June 1981, approximately 9, 21, 50 and 82 months after seeding, general ratings of the grasses were recorded to assess their persistence and vigor. The 1975 and 1976 ratings have been reported previ-

Table 2. Grasses included in the species evaluation plots.

Common name	*Variety*	*Botanical name*
Kentucky bluegrass	common, Baron, Victa, Vantage and Merit	*Poa pratensis* L.
Red fescue	Jamestown, Highlight, Fortress, Pennlawn and Kensington	*Festuca rubra* L.
Tall fescue	K-31	*Festuca arundinacea* Schreb.
Annual ryegrass	common	*Lolium multiflorum* L.
Perennial ryegrass	common, Eton	*Lolium perenne* L.
Colonial bentgrass	Exeter	*Agrostis tenuis* Sibth.
Creeping bentgrass	Emerald	*Agrostis palustris* Huds.

Table 3. Rates and composition of seed mixtures sown in the species evaluation plots.

Grass	*Seeding rate (kg/ha)*	*Composition of mixture by weight (%)*
Baron Kentucky bluegrass	132	100
Victa Kentucky bluegrass	132	100
Vantage Kentucky bluegrass	132	100
Merit Kentucky bluegrass	132	100
Common Kentucky bluegrass	132	100
Jamestown red fescue	176	100
Highlight red fescue	176	100
Fortress red fescue	176	100
Pennlawn red fescue	176	100
Kensington red fescue	176	100
K-31 tall fescue	176	100
Common annual ryegrass	220	100
Common perennial ryegrass	220	100
Eton perennial ryegrass	220	100
Exeter colonial bentgrass	44	100
Emerald creeping bentgrass	44	100
Victa Kentucky bluegrass, Manhattan perennial ryegrass*	176	50,50
Vantage, Victa, common, Windsor Kentucky bluegrass†	176	45,30,15,10
Exeter, annual ryegrass	132	17,83
Exeter, Highlight	132	17,83
Exeter, Highlight, annual ryegrass	132	17,66,17
Exeter, K-31	132	17,83
Highlight, K-31	176	50,50
Highlight, Baron	176	63,37
Highlight, annual ryegrass	176	75,25
Highlight, K-31, annual ryegrass	176	38,38,25
Baron, K-31, annual ryegrass	176	25,50,25
K-31, annual ryegrass	176	75,25

* Sports Turf

† Transition Blend

ously (Palazzo 1976). Also, in October 1978 the three replications of Baron Kentucky bluegrass, Jamestown red fescue and K-31 tall fescue from the sludged area were sampled for elemental analysis. The plant tissue was washed in distilled water, oven-dried at 60 °C, and ground in a stainless steel Wiley mill using a 30-mesh sieve. Samples were wet-digested and analyzed for potassium, phosphorus, calcium and magnesium with an autoanalyzer according to the methods of Steckel and Flannery (1971). For metal analysis, the plant material was digested with a mixture of nitric and perchloric acid and then analyzed by atomic absorption spectrophotometry (Black 1965).

RESULTS AND DISCUSSIONS

Soil amendment plots

The dredged soils (control) were acidic (pH 2.4) and infertile (Table 4). Applications of dolomitic limestone, along with either sewage sludge or commercial fertilizer and topsoil, increased the soil fertility and pH to more optimal levels in the top 20 cm of soil. Only total soluble salts and exchangeable sodium (data not shown) were unaffected by either treatment.

Applications of sewage sludge significantly increased the organic nitrogen, total nitrogen and organic carbon over the fertilized treatments, which were similar to the control soil. The ferti-

Table 4. Mean fertility status at three depths four years after sewage sludge and fertilizer applications.

Soil characteristic	*Control*	*Fertilizer plots*			*Sludge plots*		
	0-20 cm	*0-20*	*20-40*	*40-60 cm*	*0-20*	*20-40*	*40-60 cm*
pH	2.4	4.7	3.3	3.0	4.8	3.1	3.6
Soluble salt (mmhos/cm)	1.22	1.44	2.79	2.70	1.49	2.10	1.25
Exchangeable cations (meq/100g)	1.86	20.29	31.24	25.64	18.78	1.70	24.44
Exchangeable Ca (meq/100g)	1.2	13.33	20.00	16.88	14.37	8.75	19.38
Exchangeable Mg (meq/100g)	0.51	6.69	11.04	8.50	4.26	2.83	4.82
Exchangeable K (meq/100g)	0.10	0.26	0.20	0.26	0.15*	0.12	0.24
Total N (%)	0.022	0.028	0.033	0.045	0.121†	0.034	0.034
Organic C (%)	1.0	0.9	2.1	1.8	2.6*	1.4	2.4
Total P (ppm)	215	859	443	387	1150	640	1233
Organic N (%)	0.022	0.028	0.033	0.044	0.121†	0.033	0.034

* Values differ significantly at the 5% level within the 0-20 cm depth.
† Values differ significantly at the 1% level within the 0-20 cm depth.

Table 5. Total and extractible metal concentrations in soils ($\mu g/g$).

	Control	*Fertilizer plots*			*Sludge plots*		
	0–20 cm	*0–20*	*20–40*	*40–60 cm*	*0–20*	*20–40*	*40–60 cm*
				Total			
Zinc	16.2	30.3	28.6	40.7	227.3†	46.2	55.0
Copper	4.4	4.0	5.7	4.9	94.5†	13.7	8.5
Chromium	32.4	39.7	24.7	46.7	132.7†	49.9	34.6
Lead	16.5	16.9	19.2	17.3	60.8†	20.0	23.1
Nickel	14.3	18.3	21.1	32.4	29.6*	36.0	30.5
Cadmium	1.6	2.0	1.9	2.5	3.2*	2.8	2.8
				Extractible			
Zinc	1.3	2.3	1.3	0.9	66.3†	8.5	6.5
Copper	1.1	0.9	0.7	0.3	41.4†	3.6	1.6
Chromium	<0.1	<1.0	<0.1	<0.1	<0.1	<0.1	<0.1
Lead	<0.1	<1.05	<0.65	<0.10	25.5*	1.1	0.9
Nickel	1.2	1.3	1.7	2.09	5.4	11.2	8.7
Cadmium	<0.1	<0.1	<0.1	<0.1	0.78†	0.11	0.10

* Values differ significantly at the 5% level within the 0–20 cm depth.
† Values differ significantly at the 1% level within the 0–20 cm depth.

Figure 1. Growth of grasses one year after seeding. The grasses in the background were grown on a plot treated with sewage sludge; the grasses in the foreground were grown on a plot treated with commercial fertilizer and topsoil.

lized soils contained higher contents of exchangeable potassium, which was related to the application of commercial fertilizers. The application of sewage sludge did not appreciably increase the potassium content of the soil. The 25-metric ton/ha application of dolomitic limestone was primarily responsible for the increase in soil pH and exchangeable calcium and magnesium in both the sludged and fertilized soils. Both applications greatly increased the amount of phosphorus.

At the lower soil depths the soils receiving fertilizer or sewage sludge were generally more fertile than the untreated or control soil (Table 4). This probably resulted from the downward movement of these soil components since soil incorporation, or tillage, occurred to a depth of only 20 cm. Within the sludged soils the pH, total nitrogen and organic nitrogen decreased with depth. Within the fertilized soils the pH and total phosphorus decreased with depth, while soluble salts, exchangeable cations, exchangeable calcium and magnesium, organic nitrogen, total nitrogen, and organic carbon increased. At the lower depths the fertilized soils were higher in soluble salts and exchangeable calcium and magnesium and lower in total phosphorus than the sludge soils.

The sludged soils contained greater amounts of total zinc, copper, chromium, lead, nickel and cadmium and extractible zinc, copper, lead and cadmium then the fertilized soils (Table 5). There were significant differences in the extractible forms of chromium and nickel between the two soil treatments. Although the quantity of metals increased, the final concentrations were still within the range typically found in soils (Allaway 1968).

The greatest concentration of metals was in the top 20 cm of soil, or within the plow layer. Boswell (1975) and Williams et al. (1980) also found accumulations of metals near the soil surface.

The extractible forms of zinc, copper and nickel moved through the soil profile more than the total forms of these elements did (Table 5). Concentrations of extractible forms of zinc, copper and nickel were 4.4 to 7.2 times greater at the 20–40 and 40–60 cm depths in sludged soils than in fertilized soils. Increase in total metal concentrations only ranged from 0.9 to 1.7. Nickel was the only element in extractible form found to be in greater concentration at the lower soil depths. Only minor or no increases were observed at the lower soil depths for total and extractible chromium, lead and cadmium.

Plant yields were greater in plots receiving sewage sludge than those receiving fertilizer. The greater growth of grasses in the sludge area after one season is shown in Figure 1.

Figure 2. Species evaluation plots one year after seeding.

Table 6. Soil cover and heights of grasses in May 1975.

Grass	*Soil cover (%)*	*Height (cm)*
Kentucky bluegrasses	60–85	5–18
Red fescues	80–90	12–20
K-31 tall fescue	90	25
Common annual ryegrass	85	60–75
Common perennial ryegrass	90	30–45
Eton perennial ryegrass	90	20
Exeter colonial bentgrass	60	12
Emerald creeping bentgrass	80	5

Species evaluation plots

Ratings. Periodic ratings were taken of the various grasses sown in the species evaluation plots within the sludge area (Fig. 2). In May 1975, nine months after seeding, a preliminary visual analysis showed good seed germination and seedling vigor for all grasses tested, indicating that the amended soil could support initial plant growth (Table 6.). There were only small differences among varieties at this time (data not shown). The Kentucky bluegrasses provided fair to good soil cover. The fescues were considered acceptable, with both good cover and good color. K-31 tall fescue provided good cover and was taller than the red fescues and bluegrasses. The annual and perennial ryegrasses were growing vigorously and were taller than all other species. Eton perennial ryegrass, an improved variety, developed a dense uniform vegetative cover and was not as tall as common annual or perennial ryegrass. The two bentgrass species had fair to good soil cover and were light green.

Of the seed mixtures tested during these preliminary ratings (data not shown), those that contained annual or perennial ryegrass developed a good vegetative cover (>95%). However, it was evident that the ryegrasses were tall, aggressive and overly competitive with all other species in this trial. All other mixtures studied gave fair to good soil covers.

Table 7. Quality ratings of species evaluation plots.

Grass	*Quality rating** *May 1976*	*Oct 1978*
Common Kentucky bluegrass	6	8
Baron Kentucky bluegrass	8	9
Victa Kentucky bluegrass	9	8
Vantage Kentucky bluegrass	8	9
Merit Kentucky bluegrass	9	8
Jamestown red fescue	6	4
Highlight red fescue	8	5
Fortress red fescue	9	3
Pennlawn red fescue	9	3
Kensington red fescue	6	1
K-31 tall fescue	6	8
Common annual ryegrass	4	0
Common perennial ryegrass	5	0
Eton perennial ryegrass	5	0
Exeter colonial bentgrass	7	0
Emerald creeping bentgrass	7	0
Victa Kentucky bluegrass, Manhattan perennial ryegrass	6	7
Vantage, Victa, common, Windsor Kentucky bluegrass	8	8
Exeter, annual ryegrass	3	2
Exeter, Highlight	8	3
Exeter, Highlight, annual ryegrass	6	3
Exeter, K-31	7	7
Highlight, K-31	8	6
Highlight, Baron	9	8
Highlight, annual ryegrass	5	4
Highlight, K-31, annual ryegrass	5	6
Highlight, Baron, annual ryegrass	7	9
Baron, K-31, annual ryegrass	6	8
K-31, annual ryegrass	4	7
$LSD_{0.05}$†	2	2

* Quality rated from 0 = poorest to 10 = best.

† Least significant difference test at the 5% level of probability.

In May 1976, 21 months after seeding and after the plants had completed one full growing season, the grasses were again rated (Table 7). When the grasses were seeded alone, the Kentucky bluegrasses and red fescues produced a good soil cover, but there were differences among varieties. Common Kentucky bluegrass and Jamestown and Kensington red fescue received lower ratings than other varieties within their species. The ratings of the annual and perennial ryegrasses were relatively low, mostly due to lodging. Eton perennial ryegrass, which performed well earlier in the study, died out slightly and became spotty. K-31 tall fescue also had lower ratings due to lodging. The bentgrasses maintained fair to good soil covers.

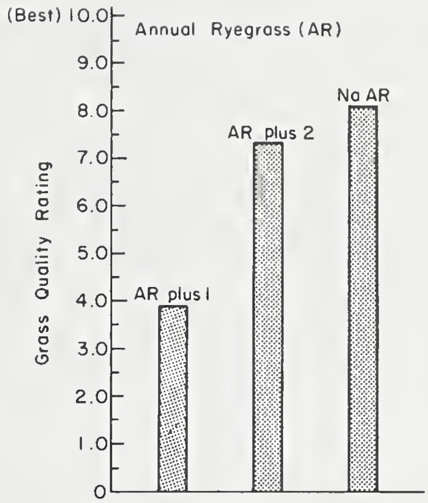

Figure 3. Improvement in grass quality when reducing the amount of annual ryegrass in seed mixture.

In a greenhouse study, Murray and Foy (1978) found that Highlight red fescue produced greater yields, on a dry weight basis, than Jamestown in soils with a pH of 4.6. They also observed that the yield of Victa Kentucky bluegrass was greater than Baron, which was greater than Vantage; the ratings of these varieties were in the same general order as in this study.

In May 1976 the mixtures containing annual ryegrass, which had done well earlier, received the lowest rating (Table 7, Fig. 3). The ryegrasses were overly competitive with the other species during establishment, and had lodged and were smothering the other grasses. These mixtures contained 25% by weight of annual ryegrass, or 44 kg/ha. Grasses in mixtures that did not include annual ryegrass were more vigorous and provided a good soil cover. Stuckey et al. (1980) also found decreases in the percentage of perennial ryegrass after a similar time on highly acidic mine spoils that were amended with sewage sludge.

In October 1978, 50 months after sludge application, the best ratings were for Kentucky bluegrass varieties and K-31 tall fescue, either alone or in mixtures (Table 7). There were no consistent differences among varieties within species. The bluegrasses were visibly shorter and provided the best soil cover, with an average rating of 8.3 (Fig. 4). K-31 tall fescue also provided good soil cover but was taller (Fig. 5). The soil surface in the plots containing tall fescue also contained greater amounts of litter, which had accumulated from the previous year's growth. The red fescues, which

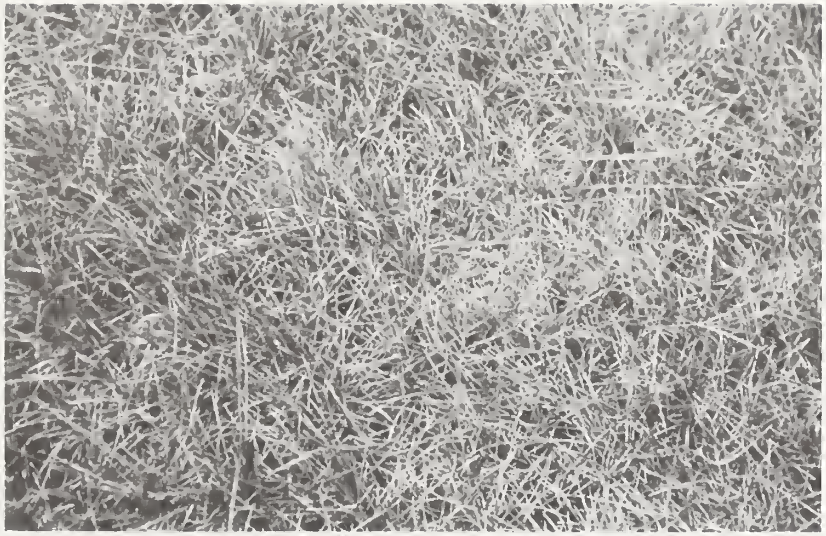

Figure 4. Baron Kentucky bluegrass 50 months after seeding.

Figure 5. K-31 tall fescue 50 months after seeding.

Figure 6. Pennlawn red fescue 50 months after seeding.

Figure 7. Kentucky bluegrass 82 months after seeding.

Table 8. Mean percent soil coverage and species composition ratings, June 1981.

Grass	Rating (%) Total soil cover	Sown grass*
Kentucky bluegrasses (5)†	76	81
Red fescues (4)	62	22
Tall fescue (1)	70	53
Annual ryegrass (1)	78	0
Perennial ryegrasses (2)	59	0
Bentgrasses (2)	49	0
Mixtures including Highlight (7)	63	32
Mixtures including Baron (3)	73	64
Mixtures including tall fescue (5)	49	44
Mixtures including bentgrass (4)	63	0
Mixtures including annual ryegrass (7)	64	0

* Sown grasses = percent of total soil cover consisting of grasses sown in 1974.

† Numbers in parentheses indicate the number of varieties or mixtures used in determining rating.

Table 9. Elemental analysis of grass samples in October 1978.

Grass	N (%)	P (%)	K (%)	Zn (%)	Cu (%)	Cr (%)	Pb (%)	Ni (μg/g)	Cd (μg/g)
Baron Kentucky bluegrass	2.22 a*	0.28 b	1.60 a	131 a	10 a	11 a	5 a	2 a	0.5 a
Pennlawn red fescue	2.35 a	0.30 b	1.42 a	291 a	8 a	10 a	6 a	3 a	0.6 a
K-31 tall fescue	1.98 a	0.45 a	1.47 a	74 a	9 a	10 a	6 a	2 a	0.7 a

* Concentrations of individual elements in columns followed by the same letter were not significantly different at the 5% level of probability according to the Duncan's Multiple Range Test (Little and Hills 1978).

had performed well during earlier ratings, did not rate as highly this time (Fig. 6). The grasses were clumpy and not as tightly knit as the soil cover produced by the Kentucky bluegrasses. The Pennlawn and Jamestown varieties, which had not performed as well earlier, received slightly higher ratings than the other red fescues. Perennial and annual ryegrasses and the bentgrasses had almost disappeared from the plots.

The site was again evaluated in June 1981, 82 months after seeding. The individual experimental plots containing less adaptable species (bentgrasses and ryegrasses) had been invaded by more adaptable grasses from neighboring plots. When sown alone or in mixtures, the Kentucky bluegrasses were the most dominant species in their plots and provided the best soil cover (Table 8, Fig. 7). They were followed by tall fescue and the red fescues.

Chemical analysis. In 1978, Baron Kentucky bluegrass, Pennlawn red fescue and K-31 tall fescue were sampled and analyzed. No significant differences were noted for any of the elements except phosphorus (Table 9). Baron Kentucky bluegrass and Pennlawn red fescue contained significantly lower concentrations of phosphorus than K-31 tall fescue. Pennlawn red fescue contained higher, though not significantly different, concentrations of zinc than Baron Kentucky bluegrass and much more than in K-31 tall fescue. Pennlawn red fescue contained a mean zinc concentration of 291 μg/g, which is above the normal limits for plants (Allaway 1968) and could be a reason for the poor growth of this species. All other elements were in the range considered normal for plant growth (Allaway 1968), with the possible exception of potassium, which could be considered low (Martin and Matocha 1973).

CONCLUSIONS

The dredge spoils in this study were low in soil pH and fertility. Applications of dolomitic limestone in combination with either sewage sludge or commercial fertilizer and topsoil improved conditions for plant growth at the site. These amendments increased soil pH, phosphorus and ex-

changeable calcium and magnesium. Sludge applications increased soil exchangeable potassium. Exchangeable sodium and total soluble salts were unaffected by the treatments.

Sludge applications increased the metal concentrations of soils but not to excessive levels. The greatest metal concentrations were within the plow layer (the upper 20 cm of the soil profile). Below this depth, only the concentrations of the extractible forms of zinc, copper and nickel were increased.

In the species evaluation plots the ryegrasses became established more quickly than the other grasses studied. This was due to their rapid germination and development rates. K-31 tall fescue established more rapidly than the red fescues, which were quicker than the Kentucky bluegrasses.

After 21 months the Kentucky bluegrasses and red fescues, seeded alone or in combinations not including ryegrasses, were the most desirable species for providing the best soil cover. At this time the ryegrasses had lodged and partially smothered other grass species. The bentgrasses maintained a fair to good soil cover early in the study but did not persist.

All varieties of Kentucky bluegrasses and red fescues performed equally well, except for common Kentucky bluegrass and Jamestown and Kensington red fescue, which received lower ratings. K-31 tall fescue also lodged because of its previous rapid growth and received lower ratings than the red fescues and bluegrasses.

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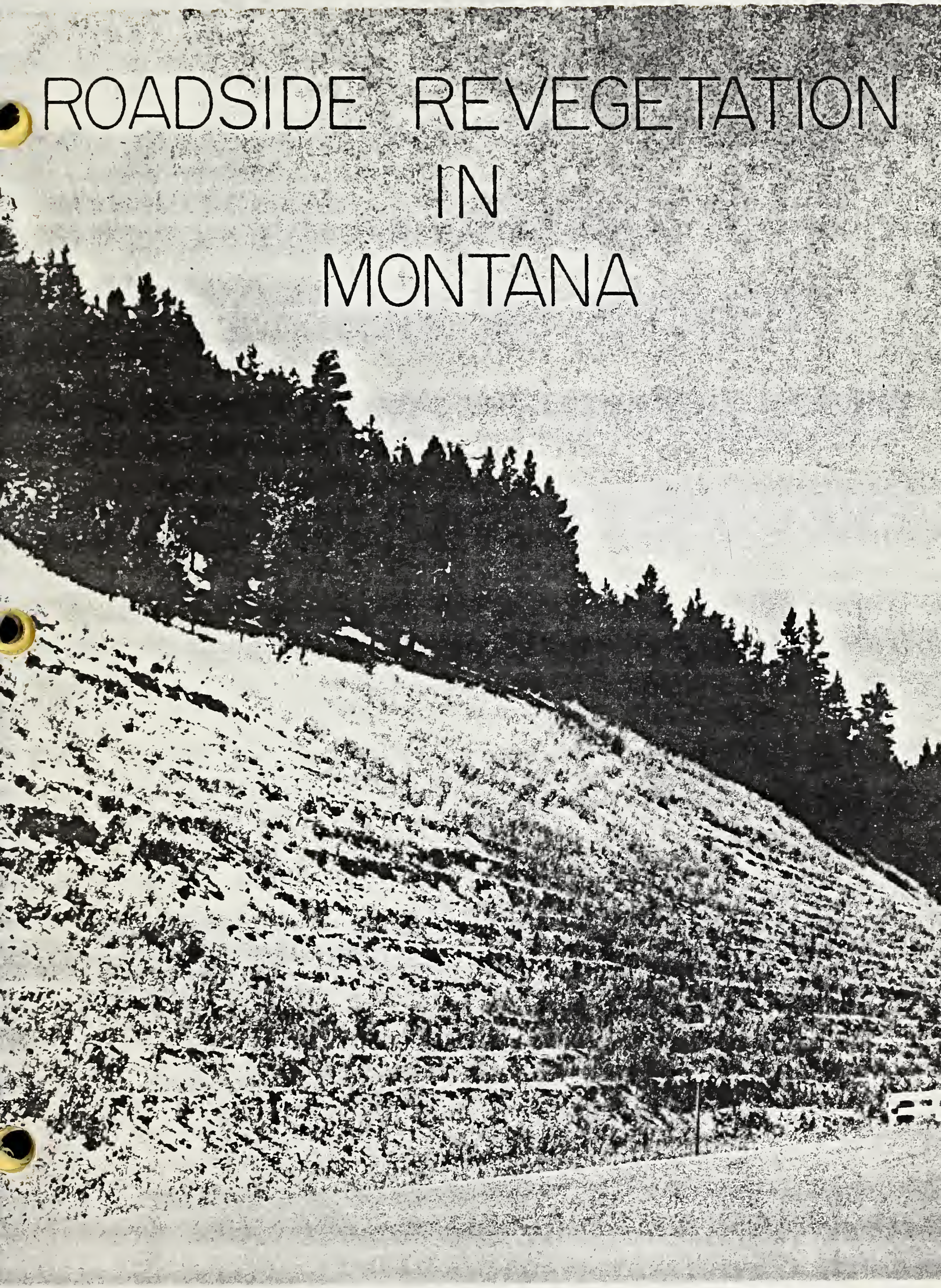
ROADSIDE REVEGETATION IN MONTANA



PREPARED BY THE

STATE OF MONTANA
DEPARTMENT OF HIGHWAYS
PRECONSTRUCTION BUREAU

DECEMBER 1974

cover photo: I 15 south of Jefferson City.
The terraces or steps have been formed in decomposed granite and seeded as the cut progressed downward. This technique is more extreme than rough grading or serrating, which is used to hold topsoil. Vegetation was established before the road was opened for travel. The guardrail posts have been stockpiled prior to installation.

TABLE OF CONTENTS

I. INTRODUCTION

This report was prepared by the Montana Department of Highways in response to the directives set forth in SENATE JOINT RESOLUTION 55 of the 1974 Legislative Session. The Senate and House of Representatives jointly resolved:

> "That the Department of Highways is hereby directed to undertake a thorough review and study of highway reseeding practices and policies in Montana, to prepare a report and make recommendations with respect to such practices and policies, and to prepare suggested legislation for the consideration of the governor and the 1975 Legislature. Matters requiring special attention include topsoil conservation and reclamation in connection with all highway projects; exploration of the safety features (or hazards) of borrow pits, exploration of grading of borrow pits from an ecological point of view (studying the best method of minimizing weed invasion and erosion, and possibilities of maximizing productivity); and investigating reseeding practices on county roads and the status of reseeding on such roads, in particular whether the county commissioners are complying with their responsibilities under Section 32-2813, R.C.M. 1947."

Highway rights-of-way are presently being reseeded following construction for several reasons. The most important function

of reseeding is erosion control. Erosion occurs naturally and/or can be man-induced. Natural erosion is a geological process over which man has little or no control; it may be slow or rapid depending on many inter-related factors.

When erosion exceeds the natural rate, becoming unusually destructive, it is called accelerated. Accelerated erosion is caused by two factors: the removal of natural cover, and the exposure of erosive soils. Highway construction by its very nature does remove natural cover and expose erosive soils. In many instances, the exposure of erosive soils cannot be avoided. Disturbed areas can be covered by an erosion-resistant surface, or a protective ground cover can be established.

Protection against erosion provided by vegetation is effected through the binding force of the root system, the dissipation of impact forces by the aerial canopy, and the retardation of runoff and increase in infiltration by the plant stems and root crowns. The structural functionality of the subgrade foundation, shoulders, inslopes, backslopes and drainages can be enhanced for longer periods when erosion is controlled. Thus the integrity of the driving surface can be maintained.

If erosion is controlled or reduced, sedimentation or the deposition of eroded materials is also reduced. Thus the establishment of vegetation cover serves a second inter-related function. National and state concern over an increase in erosion and sedimentation has grown within the last decade. This concern is reflected in water quality legislation that is

giving more consideration to sedimentation.

A third function of reseeding is the improvement of the visual characteristics of completed highways. Recent trends in highway design are complementary to the natural terrain and have greatly improved roadside aesthetics. Cuts and fills, however, are still necessary. Reseeding to establish ground cover in areas previously left bare now produces a positive visual impact.

Figure 1: I 15 Jefferson City North
Building interstate through rough terrain requires large cuts and fills; the lanes are staggered and blended with the natural contour of the land. Natural vegetation has been saved and backslopes have been terraced to aid in slope stabilization and early plant establishment. The old road, (center picture), disturbed less land and did not present the problems of revegetation that modern dual lane highways do.

Figure 2: I 15 Boulder North
Properly designed highways are safer, easier to revegetate, cost less to maintain and have a positive visual impact on the traveler.

Policies and practices of reseeding areas disturbed by highway construction have only recently evolved. The public demand for a functional transportation system has, in part, been met. Environmental considerations, including erosion control, aesthetics and economic priorities, are becoming more prominent in the public view. Engineering principles and construction

practices are changing not only as a result of these new concerns, but also because the "state of the art" is changing. Several years lag must occur before evaluations can be made. Highways builders are now finding that rights-of-way left bare not only cause higher maintenance costs over the life of the highway, but also can become safety problems and eyesores.

Herewith, the statutes governing reseeding of areas disturbed by highway construction are presented chronologically. A historical review of departmental practices and current methods, as they relate to special provisions and construction specifications, are presented pictorially. Comments and legislative recommendations are made for consideration by the Governor and the 1975 Legislature.

II. LEGAL REQUIREMENTS

Prior to 1961, neither the Montana Department of Highways nor the Boards of County Commissioners was under statutory directive to reseed or re-establish sod cover in areas disturbed by road construction. Nevertheless, revegetation efforts were being carried out in scattered areas. Local soil conservation districts,public individuals, and a general public interest in aesthetics and erosion control were motivating forces.

In 1961, the 37th session of the Montana Legislature enacted House Bill 124 as Montana's first highway seeding law entitled:

"AN ACT TO PROVIDE FOR THE SEEDING OF PERENNIAL GRASS COVERS ON NEWLY DISTURBED RIGHT-OF-WAY AREAS, INCLUDING STATE AND FEDERAL HIGHWAYS,

COUNTY ROADS, IRRIGATION DITCHES, DRAIN DITCHES, BORROW PITS, SLOPES, ROAD SHOULDERS OR OTHER TYPES OF CONSTRUCTION; AND PROVIDING A REPEALING CLAUSE."

Section One, as follows, sets forth the duty of the State Highway Commission:

"Whenever a highway, state or federal, is constructed in any part of Montana, it shall be the duty of the state highway commission to see that borrow pits, slopes and road shoulders be seeded to an adaptable perennial grass or combination of perennial grasses and/or legumes wherever it seems suitable for establishment of perennial grass covers using seed meeting certified standards. Time and method of seeding, fertilizing practices and grass species shall be recommended and specified jointly by the Montana extension service, soil conservation service and experiment station. Every effort will be made to establish a sod cover on the newly cut over areas."

Section Two of the act sets forth the duties of county commissioners:

"Whenever the natural sod cover is disturbed on right-of-way for construction of county roadways, irrigation ditches, drain ditches or other types

of construction on such right of way, it shall be the duty of the county commissioners to see that such disturbed areas are seeded to an adaptable perennial grass or combination of perennial grass and/or legumes whenever they believe it is practical to do so, using seed meeting certified standards. Time and method of seeding, fertilizing practices and grass species shall be recommended and specified by the Montana extension service. Every effort will be made to establish a sod cover on the newly cut-over area."

Section Three repeals all conflicting statutes or parts thereof as follows:

"All acts or parts of acts in conflict herewith are hereby repealed."

The 39th Legislature in 1965 re-codified the statutes pertaining to the Montana Department of Highways. In doing so, minor changes were made in the highway seeding statute; however, the intent and applicability remained unchanged.

In 1974, the Legislature directed the Department of Highways by way of House Bill 634 to classify open range areas according to the degree of traffic hazard and fence out livestock in the more hazardous areas. This statute in part amended the highway seeding law so as to include a new section covering seeding and cropping of right-of-way in fenced, open-range areas.

Sections 2412 and 2801 of Title 32, Revised Codes of Montana, 1947, are the present statutes which govern seeding of right-of-way by the Montana Department of Highways and the individual Montana counties:

32-2412 Seeding along highways.

(1) After a federal-aid or state highway is constructed, the department shall seed borrow pits, slopes and shoulders to an adaptable perennial grass or combination of perennial grasses and legumes whenever establishment of perennial grass covers seems suitable. The seed shall be certified.

(2) The department shall seek joint recommendations and specifications as to time and method of seeding, fertilizing practices and grass species from the Montana extension service, the experiment station and the soil conservation service.

(3) After a right-of-way in open range has been fenced, pursuant to 32-2426 or 32-2427 the department may seed the land within the fence to a grass which may be cropped for hay and may lease such lands or sell the right to take such hay to qualified persons.

32-2813 Reseeding of right-of-way areas.

(1) Whenever the natural sod cover on right of way areas is disturbed by construction of county roads, irrigation ditches, or otherwise, the board of county

commissioners shall require that such disturbed areas be seeded to an adaptable perennial grass or combination of perennial grasses and legumes. Every effort shall be made to establish a sod cover on the disturbed area.

(2) All seed used shall meet certified standards.

(3) Time and method of seeding, fertilizing practices and grass species shall be those recommended by the Montana extension service.

In addition to compliance with the statutorial reseeding responsibilities as set forth above, the Montana Department of Highways must satisfactorily meet the regulations of other jurisdictional bodies. The Federal Highway Administration has prescribed policies and procedures for roadside development on Federal aid projects which includes reseeding since the enactment of the Highway Beautification Act of 1965. The United States Forest Service and Bureau of Land Management may also require that specifications and policies on seeding, slope management and grass species be met when highway projects disturb surface under their jurisdiction.

III. HISTORICAL REVIEW

The history of highway reseeding policies and practices in Montana appears to follow three distinct phases. Prior to 1960 highway rights-of-way were not seeded as a general practice following construction. In 1961 the Department of Highways

was required by law to seed rights-of-way. During the next three years, disturbed areas were seeded, but success was marginal. The need for research became very evident By the mid-sixties the Department's reseeding effort entered its third and present phase, that of research and application.

Pre-1960

Prior to 1960, the Department of Highways had not developed a seeding policy, nor was there any effort made to reseed disturbed areas on a statewide basis. Revegetation, when attempted, was undertaken with initiative at the local level, either by highway maintenance personnel or county road crews. These early, scattered attempts were supervised by individual local Soil Conservation Districts and the U.S. Soil Conservation Service. More often than not, the establishment of ground cover was left to natural plant succession.

Approximately 70 percent of Montana's present rural Primary System had been completed prior to 1960(5). Thus several thousand miles of Montana roadside right-of-way was not reseeded following construction. Many stretches still remain bare or, in some cases where natural conditions were favorable, varying degrees of revegetation have occurred.

In February,1960,the Department awarded its first seeding and mulching contracts. Approximately 145 acres of Interstate right-of-way in the Superior-Alberton and Drummond-Garrison vicinities were to be reseeded in addition to 132 acres near Crow Agency.

The specifications for these two contracts were developed in cooperation with the local Soil Conservation Service offices after reviewing information received from other states and the seed industry. Three additional contracts were awarded during 1960.

These initial reseeding contracts and the appearance of the Interstate system in Montana marked the beginning of a reseeding policy for highway rights-of-way. Within the next year the Department would be required by law to reseed all areas disturbed by construction.

Implementation of a New Law: The Need for Research

Following the enactment of the Montana Highway Seeding Law in 1961, the Department, under a legislative directive to reseed rights-of-way, established a Highway Seeding Committee. The Committee, composed of personnel from the Soil Conservation Service, Montana Agricultural Experiment Station, Montana Extension Service, and Department of Highways, was responsible for recommendations on time and method of seeding, fertilizing practice, and grass species.

During the first several years of the Committee's operation, nineteen seeding contracts were awarded by the Department of Highways. Early results did not meet expectations. Field records on these early reseeding attempts were incomplete, if recorded at all. Information necessary to support and/or revise the Committee's recommendations and departmental field practices was not available. Research was needed to effectively deal with

a wide cross-section of revegetation problems never before encountered during highway construction in Montana.

Research and Application

In 1964, under the guidance of the Seeding Committee, the Department initiated studies, surveys and field research projects to provide the practical working knowledge absent when the seeding law was enacted. Many of these studies and research projects are still underway, providing a continual refinement of revegetation techniques.

Research and implementation of recommendations therefrom has taken time. Results can be observed in two or three years in some instances; other cases take longer. As positive results become available, changes in construction specifications and special provisions are made. Major advancements made between the commencement of research and the present include topsoil salvaging, slope rounding and flattening, a more precise seeding period to coincide with optimum growth factors and geographic locations, variable slope and surface manipulations, two step application of seed-mulch and fertilizer and most recently, stage construction.

Before moving into a discussion of the Department's present revegetation practices, an important point must be made. Not all roadsides can support a dense stand of perennial grass, no matter what reasonable revegetation techniques are used.

Vegetation on each roadside can only reach the state of development possible under the natural environmental conditions

present at the site. Factors which affect the vegetation are: amount and timing of precipitation, texture and fertility of the soil, exposure, elevation, latitude, and length of the growing season. Many roadsides do have less vegetation than would seem desirable, but comparison with vegetation on the other side of the right-of-way fence often shows that the roadside vegetation is similar.

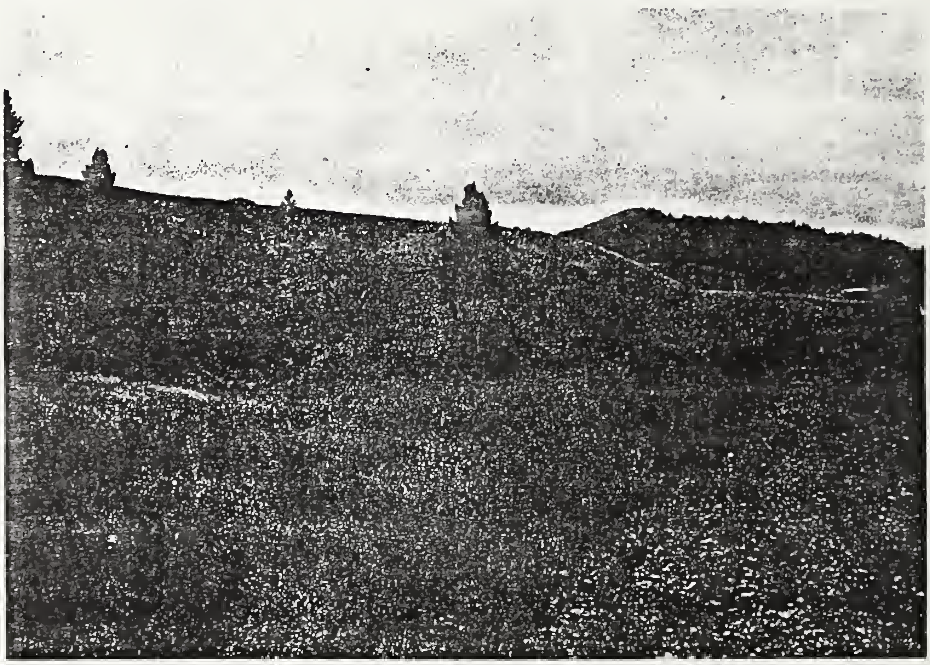


Figure 3: I 15 Boulder North
Many rights-of-way reseeded in the past 10 years have better vegetation cover than do adjacent properties due to protection from over-grazing.

Another point to consider is that not all areas which are inadequately revegetated are causing a serious erosion problem. The Department monitors roadsides for erosion and safety problems. When money is available, the most severe cf these areas

are corrected. Financial limitations often perpetuate "eyesores" in favor of correcting more serious problems.

Older roads which are inadequate for today's higher traffic volumes and speeds are being upgraded, as funds become available. This reconstruction will eventually upgrade projects which were built before the Department had a revegetation policy.

IV. CURRENT REVEGETATION PRACTICES

The following discussion outlines the practices and procedures for revegetation currently followed by the Department. The complete specifications may be found in Section 17 of the Standard Specifications for Road and Bridge Construction, as adopted by the Montana Highway Commission and most recently approved by the Federal Highway Administration in October, 1974, and the "Special Provision for Erosion Control, Water Pollution and Siltation Control" (3,4).

Exposure

West and south facing slopes are characteristically more difficult to revegetate and harder to maintain a suitable protective cover.

These slopes being exposed to the direct sun for long periods of time are subject to over heating, high evaporation losses, premature germination, and over-exposure of new seedlings.

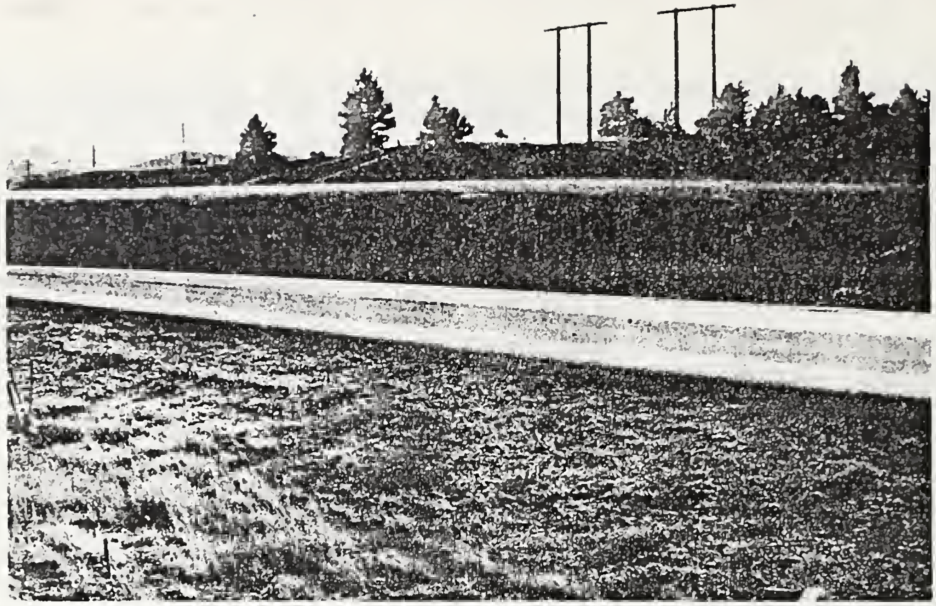


Figure 4: I 15 Montana City Exit North, Mile Post 188
East-facing backslope (left mid picture) has responded to topsoiling, seeding and favorable aspect. (Right mid-picture) This section, inadvertently missed during the topsoiling and seeding operations, has not established a suitable cover.

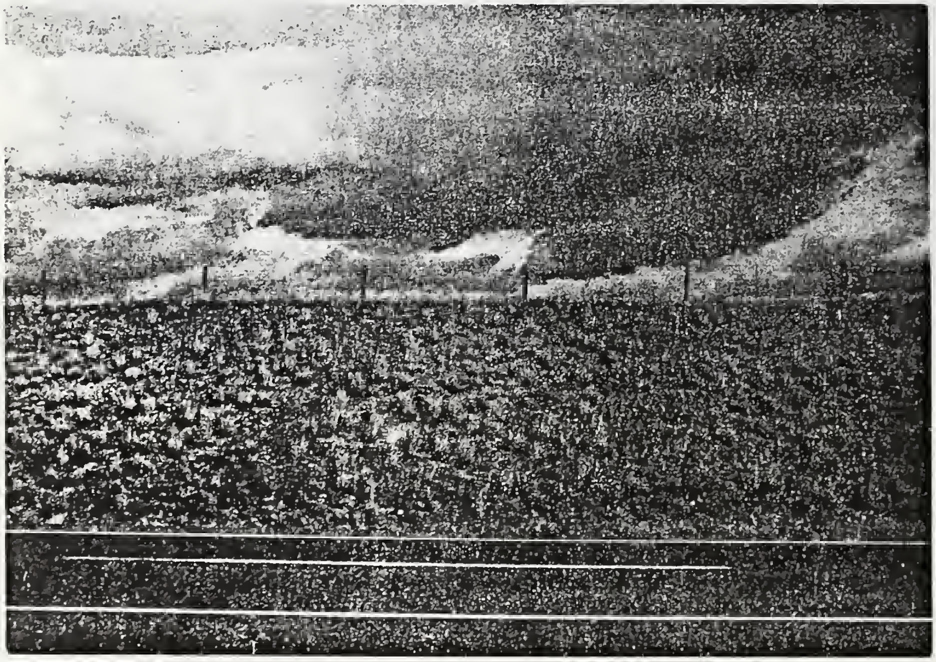


Figure 5: Montana City Exit North, Mile Post 188
This west-facing slope was treated the same as the east facing slope in Figure Four. Vegetation is sparse and will take several years to fill in.

These slopes are seeded first, receive the most topsoil and are mulched quickly after seeding. The seed must be covered immediately after application, even if by hand labor.

<u>Slope Configuration and Erosion Control</u>

Slope shape is a critical factor in establishing a stable soil surface for revegetation. The slopes are made as flat as practical, are rounded at the top and designed to protect the face and toe from flowing water. Slope design also considers the natural contour of the landscape.

Figures 6 and 7: County Roads, Whitewater South, Phillips County
These cuts were made 30 to 40 years ago, leaving backslopes steep, with turf caps that prevent desirable vegetation from establishing.

Figure 8: I 15 Montana City South
Old road cut, upper left, remains bare due to absence of topsoil, steep slope and no seeding. Mid picture: new cut has been rounded, topsoiled and seeded. Inslope has been flattened 6:1, with a wide transition zone to carry away excess water.

Long steep slopes are difficult to revegetate because water tends to flow off instead of percolating in, as it would on flatter ground. To prevent flow of water over the face of the slope, diversion ditches or dikes are constructed at the crest of the slope to divert the water to a central collector, to be transported down a drain and safely off the slope, Figure 9.

Inslopes (the area from the shoulder of the roadway to the bottom of the ditch) are graded to a 6 to 1 (horizontal to vertical) or less slope to keep water from concentrating in a narrow ditch where it could erode the toe of the cut or fill slope. If

these areas are still potentially erosive, they are protected by the use of asphalt or concrete ditch liners, or grass sod, Figures 10, 12. Water velocity is slowed at discharge points by construction of energy dissipators or rip rap, Figure 11.

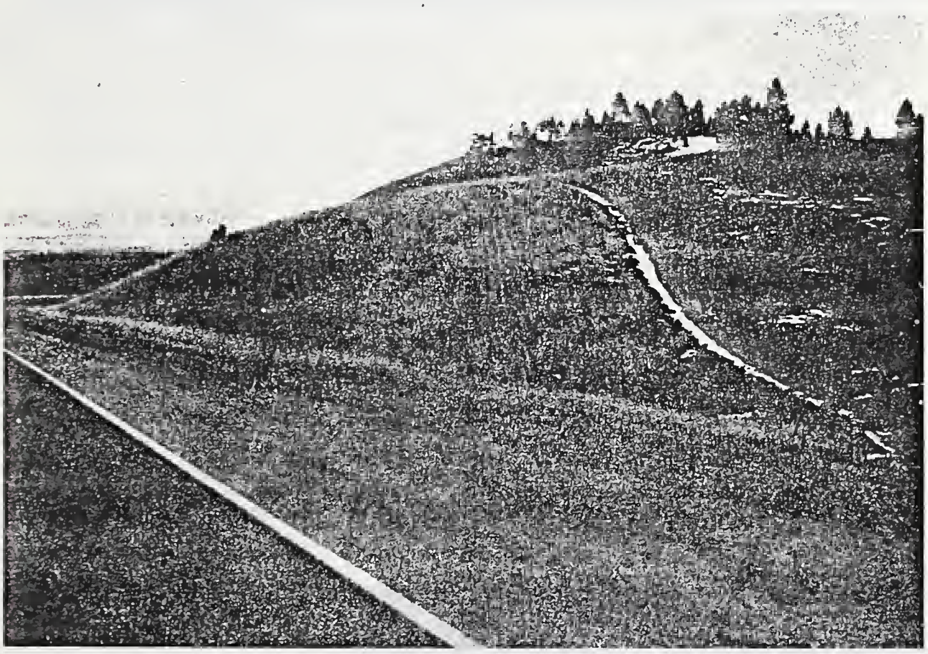


Figure 9: I 15 Boulder North
Backslope is well rounded with diversion ditch at crest to prevent water flow over the face of the slope. Upper slope face has been drill seeded; the lower has been hydroseeded because of steepness.

Figure 10: I 15 Vaughn North,
Mile Post #295
This median has been protected with a concrete ditch liner and drop inlet which will route water safely off project. Median right of ditch liner was top soiled; left received marginal topsoil.

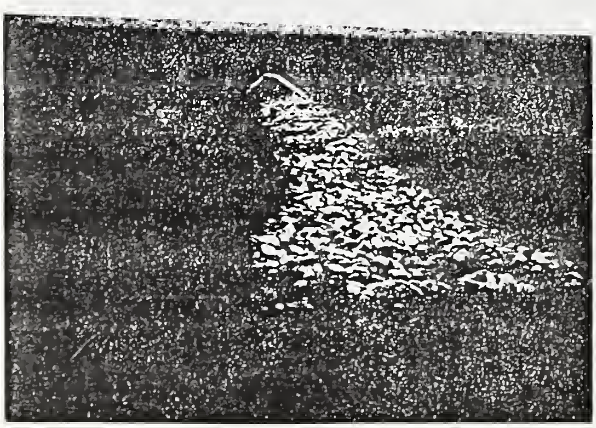


Figure 11: I 15 Vaugh North,
Mile Post #295
View of drain outlet that has been protected by riprap.

Figure 12: I 15 Boulder North
Where possible, inslopes are graded 6:1 or flatter for safety. The ditch, center, is lined with fiberglass roving and asphalt to eliminate a potential erosion problem.

Topsoiling and Seedbed Preparation

Since 1965, specifications have called for the salvaging and stockpiling of all topsoil and reapplication after the final grading has been completed. This practice has made it practical to seed and establish vegetation on the steeper slopes if the topsoil can be kept in place.

To be effective, topsoil must stay in place. To keep topsoil on a steep slope requires special techniques and proper grading methods. Slopes must be left rough with irregularities or pockets for topsoil to be caught and held. These irregularities can vary from scraper scars to uniform benches or terraces, with horizontal and vertical variations of up to four feet, depending

on the type of soil and the steepness of slope. Rough grading has always been done, but past engineering practices required a final smoothing operation to eliminate what was thought to be an objectional feature. The benches over a period of years will weather to a natural contour. In the meantime, the steps hold the topsoil, trap moisture, and stabilize the slope long enough for vegetation to become established.

Figure 13: I 15 Jefferson City South
This slope has been "mini-benched" or terraced and has responded to revegetation.

Figure 14: I 15 Jefferson City South
This close up shows how mini-benches slough to a natural contour over a period of years; the slope has remained stable long enough for vegetation to become established.

Figure 15: York Road - York Bridge West
Smooth grading will be a thing of the past. All new projects will be rough graded to facilitate holding topsoil.

Figure 16: I 15 Jefferson City South
The far right portion of this slope has been terraced or stepped for stabilization and has started to establish vegetation. The left was smooth graded and has started to slip. Water has rilled the upper portions.

Fills do not require this slope treatment method, but do require special treatments to keep topsoil in place. The subsoil in fills, as opposed to cutslopes, is generally too loose to be a good subbase for topsoiling, and must be compacted as the topsoil is applied. The best method is to apply the topsoil by pushing it into place with a tracked vehicle. The tracks not only compact the topsoil into the sub-base but leave thousands of indentations that trap seed, fertilizer, and mulch.

Fill slopes are easier to revegetate than cut slopes because they are usually flatter, which provides a better substrate

for plant growth.

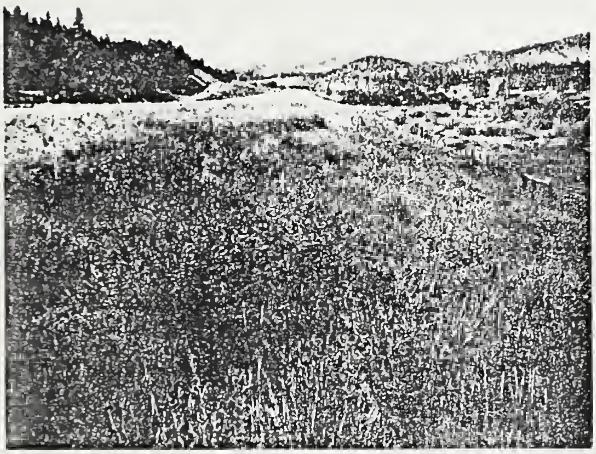


Figure 17: I 15 Clancy North

Fill slopes respond better to revegetation than do cuts.

Figure 18: I 90 Livingston East
Smooth grading, lack of top-soil and steepness make slopes difficult to revegetate.

The contractor is required to topsoil, prepare the seedbed, seed, and mulch as soon as possible after the final grading. This procedure has several advantages. Loss of topsoil is minimized. Potential for weed invasion is reduced. Additional conditioning of the seedbed is precluded. Erosion is controlled immediately by the protective mulch and the sprouting vegetation.

On recent projects, permanent vegetation is often established several years before the road is opened for use.

Seed

Seed that is purchased for use on the highway must be of high quality and contain no noxious weeds. Seed must meet the standards established by the Montana Department of Agriculture and must be grown under conditions compatible with the area where it will be planted. Preferably, the seed selected should be grown in Montana.

Usually a combination of three species is used in a seeding mixture. The grass species used and the amount of each, are dependent on the type of soil, effective precipitation, elevation, and the desired objective of the seeding.

Most roadside slopes steeper than 3 to 1 are seeded with 24 pounds of seed per acre. Slopes 3 to 1 or flatter are seeded with 12 pounds of seed per acre.

Species that are adapted to eastern Montana are:

"Fairway" crested wheatgrass	*Agropyron cristatum*
Streambank wheatgrass	*Agropyron riparium**
"Critana" Thickspike wheatgrass	*Agropyron dasystachym**

Western wheatgrass	_Agropyron smithii_*
Slender wheatgrass	_Agropyron trachycaulum_*

The following species are hardy in western Montana or moist areas in eastern Montana:

"Durar" Hard Fescue	_Festuca duriuscula_
Kentucky Bluegrass	_Poa pratensis_
Canadian Bluegrass	_Poa compressa_
"Lincoln" Smooth Brome	_Bromus inermis_
Western wheatgrass	_Agropyron smithii_*
"Critana" thickspike wheatgrass	_Agropyron dasystachyum_*
Green needlegrass	_Stipa viridula_*

Some of these grasses (those marked by an asterisk) are native to Montana. The others are commonly available exotic species which are widely used in Montana.

It is occasionally suggested that we revegetate with native species only. The major problem with this idea is that there is no commercial seed source for most native species. The Highway Department does have a program to purchase hard-to-get desirable varieties when they are available, and furnishes this seed to the seeding contractors.

Planting Dates

The time of planting is a critical factor and the Highway Seeding Committee has established specific seeding dates. The fall seeding season starts October 15th and ends when snow covers the ground or the ground is frozen. The spring seeding season

starts as soon as the ground is dry enough to permit equipment to traverse the seedbed or when the frost has left the ground if the area is to be hydroseeded. It ends April 30th in the dryer eastern portion of the state and May 20th in the intermountain region.

Timing of fall plantings is critical because the seed should not germinate until spring. Germination in the fall may result in the death of many seedlings if cold weather arrives before they become well established.

Planting in early spring gives the best results. To be successful, the seed must be placed in the soil early to allow germination and development of a vigorous plant with a large root system before the available moisture is depleted during the summer dry spell. If soil moisture becomes limited at any time during the development of the seedling, the plant will perish. To guarantee seedling establishment in eastern Montana during a normal year, the spring seeding must be completed by late April. A major disadvantage to seeding in the spring is the short period of favorable seeding time and the adverse working conditions normally encountered. After the soil becomes dry enough to work, the spring rains usually commence, thereby preventing seeding operations.

The seeding dates can be modified on a case to case basis by the Department's staff agronomist, but usually if this is done the contractor must have provisions for supplemental watering during critical periods of plant growth.

Fertilizer

The handling of fertilizer, especially nitrogen fertilizer for dryland plant establishment, is critical. Application of too much fertilizer at the time of seeding may benefit annual weeds at the expense of the grass seedlings. Too much fertilizer can over-stimulate growth in seedlings, or may "burn" the seedlings. High concentrations of nitrogen can reduce the percent of germination, if in contact with the seed for over 1 hour. Nitrogen fertilizer can be leached from the soil before the seedlings are mature enough to utilize the fertilizer effectively.

To avoid these problems, the timing, rate, and method of application must be accomplished with great care and by qualified personnel. Present practice is to apply the fertilizer at a rate well below the critical level at the seeding stage. With this method, the seedlings receive some benefit, but are protected from burning, and reduced germination. The weed problem is also reduced and leaching of nitrogen is minimized. The Department programs the bulk of the fertilizer to be applied over a period of years following seedling establishment. The mature plants are better able to use the fertilizer and respond much more favorably than if fertilizer was applied only at the seeding stage.

Mulches

From the time the soil is first exposed until a permanent cover of vegetation is established, the soil is subject to erosion by wind and water, and baking by the sun which causes

the soil to crust and reduces the moisture content. These conditions are not favorable for germination and development of desirable plants. Mulches are used to mitigate these problems.

When properly selected and applied, mulches not only protect the soil from erosion but provide a microclimate conducive for establishment of plants. Mulches hold seed in place until it can germinate, provide shade for tender seedlings, moderate temperature extremes of the soil, increase the infiltration rate of moisture, inhibit evaporation, and reduce compaction of the soil by heavy rains.

The Department uses two basic types of mulches, straw and wood fiber. The type and amount of mulch selected for a particular job depend on the type of soil, percent of slope, and conditions of climate.

Straw or native hay held in place with a light coating of asphalt is used in dry areas and areas where the soil is subject to freezing and thawing which causes the soil to heave. This mulch flexes with the soil and remains in place.

There are several disadvantages to straw and asphalt mulch. The cost of asphalt is rising with the shortage of oil. Availability of asphalt is seasonal, being dependent on road construction which ends with the arrival of cold weather. This type of mulch is the more difficult to apply. And finally, long slopes must be accessible from both top and bottom because straw cannot be blown a long distance.

Wood fiber mulch is used in high wind areas where straw would be displaced. Wood fiber mulch is a specially prepared product consisting of wood fibers of varying length which forms an interlocking mat when properly applied. The mat is stable in the wind, but is not dense enough to retard emergence of seedlings or percolation of water into the soil. Wood fiber mulch can be applied to longer slopes than straw-asphalt mulch because it can be blown farther. Additional benefits are that it requires less equipment to apply, it is less messy, it is available year around, and can be used in cold weather without special heating apparatus (asphalt must be heated in cold weather). A disadvantage is that it tends to absorb moisture from the soil (straw does not). This limits its use to areas with fairly high rainfall.

In some instances, the results achieved with wood fiber mulch were less impressive than when straw and asphalt were used. This was because seed was applied with the wood fiber mulch. As a result, some seed became suspended in the mulch and was blown away or kept from contacting the soil. This problem is discussed more fully in the section on seeding methods.

When a project is completed during the summer or is in a high wind area, the Department has developed a temporary erosion control method to protect these areas until conditions are optimum for establishment of plants. Straw or native hay is applied at a rate of one to one and a half tons per acre over a cultivated seedbed. The straw is incorporated into the soil by a special mulch tiller which punches the straw into the soil to a depth of 3 inches,

leaving half the stems above ground in uniform rows. The resulting stubble will trap snow, reduce runoff, and check erosion by wind. When conditions are suitable, seed can be applied through the anchored straw with a disc drill without any loss of protection from the stubble. No additional preparation of the seedbed is usually needed. A disadvantage of straw anchored mulch is that slopes 3 to 1 or steeper cannot be worked. Research is underway to develop a machine to operate on steep slopes.

Seeding Methods

Most areas flat enough for safe operation of machinery are seeded with a drill. Exceptions are small areas such as around slope drains and bridge ends, which are broadcast seeded. At the present time, drilling is the most successful method of seeding.

Drills equipped with press wheels place the seed in the ground at the correct depth and then compact the soil around the seed. The former helps to insure maximum establishment of seedlings, the latter prevents moisture from evaporating from the soil before germination.

Department specifications recommend that grass drills, equipped with fertilizer attachments and press wheels be used. If this type is not available, a grain drill can be substituted if converted for use with grass seed.

No mulch is required with drilling unless the soil is sandy and high loss of moisture would occur otherwise.

Unfortunately, not all areas can be drilled. The only practical method of seeding slopes 3 to 1 or steeper is the hydroseeding method.

Figure 19: I 15 Boulder North
The steep lower slope which was hydroseeded has not established as dense a vegetation stand as the upper area that was drilled.

The best results are obtained when a two or three step method is used. The seed is applied to the prepared slope using water as a carrier. Then, if the slope is not excessively steep or inaccessable, the seed is covered to a depth of 1/2 to 3/4 inch with soil. Finally, a mulch may be applied. This method insures that the seed will not be lost before conditions are suitable for growth.

In the past, seed, fertilizer and wood fiber mulch were applied in slurry form in a one-step hydroseeding process. Experience has shown that the heavier, water-soaked mulch reached the soil first. The lighter seed was on top of or suspended in the mulch, and never contacted the soil. Partially exposed seed was subject to being blown away by wind or carried away by flowing water. Results with this one-step method were often not satisfactory so it is no longer used.

Stage Construction

Until recently, highway revegetation programs were expected to establish permanent ground cover with one seeding operation. No money was allocated for additional work on jobs that were partial or complete failures.

Most jobs have some areas which could use some touch-up work. In these cases, stands of grass can be brought up to an effective vegetation cover by additional fertilization and/or seeding, or by mechanical protection from erosion.

In 1974, the Department instituted a stage construction program for revegetation which allows for reseeding,

refertilization, remulching, and/or erosion protection for areas which did not respond satisfactorily to the initial attempt. This procedure applies to all projects let after April, 1974.

V. MAXIMIZING PRODUCTIVITY ON HIGHWAY RIGHTS-OF-WAY

In addition to the normal functions of highway right-of-way, two uses have been suggested to maximize productivity: growing agricultural crops and managing for wildlife.

Highway Department procedure requires that a rancher interested in haying or otherwise utilizing a portion of state controlled right-of-way apply for an agricultural use permit from the appropriate Divisional Chief of the Field Maintenance Bureau. Such permits are granted if no conflict would exist with a more important function of the roadside. An application for a permit may be turned down for several reasons.

A major function of the roadside is to provide a reasonably safe area for a vehicle leaving the roadway surface to come to rest. If the agricultural activity would cause undue hazard to the road user, the permit may be denied. If the permitee operates his machinery in such a manner that highway traffic has to continually slow down or swerve suddenly to avoid a collision, the permit may not be renewed. In general, safety problems would tend to be most severe on roads serving high speed, high density traffic.

Another function of right-of-way is to provide a suitable substrate for the roadway. An agricultural use permit would not

be granted if the activity would endanger the roadway.

Aesthetic considerations may also influence granting a permit. If the roadway has been specifically engineered or landscaped to provide a pleasing visual aspect, agricultural activities may not be compatible.

Occasionally, more right-of-way is purchased than is necessary for immediate construction. This is done when the need for additional construction in the future is evident. In such cases, the excess right-of-way may be used in its previous manner until it is required for construction.

The second method of maximizing productivity is to manage rights-of-way for wildlife. The point has been well made that highway, railroad, and utility rights-of-way cover very extensive acreages (6,7). Many species of animals can use this land for at least a portion of their habitat.

Several studies have examined the effects of roadside mowing and special plantings on ring-necked pheasant and duck nesting success (1, 2, 6). It was shown that planting suitable cover and regulation of mowing practices can produce significant increases in game bird populations. Other animal populations also benefit.

Mowing practices of the Montana Department of Highways generally conform to published suggestions for maximizing cover for wildlife. No experimentation with special plantings to provide cover has been done because we have had no indication that there is a problem with the species presently planted.

Conflict may arise between use of rights-of-way for agriculture and wildlife habitat. The sections of rights-of-way which could be managed most beneficially for game birds are the areas which traverse intensively cultivated regions. In such areas, nesting and wintering cover is at a premium. This is one of the major reasons why pheasant populations, in particular, have declined. Demand for additional cultivatable land in these areas, including use of highway rights-of-way, is often high.

The Department of Fish and Game has discussed with the Department the possibility of managing such critical areas for game birds. To date, these critical areas have not been defined by their Regional Game Managers, so no further actions have been discussed or taken.

VI. BORROW PIT DESIGN

Roads are built on grades which are elevated above the level of the adjacent land to minimize drifting of snow, and to provide a compacted base for the roadway surface. Extra material must be appropriated from somewhere to build an elevated roadway.

Prior to 1960, this material was borrowed as close to the roadway as possible to minimize cost of right-of-way and to simplify transportation of the material. This type of construction left deep borrow pits with steep backslopes, which were very hazardous to out of control vehicles. About 70 percent of

Montana's present rural Primary System and most of the county roads were built in this manner.

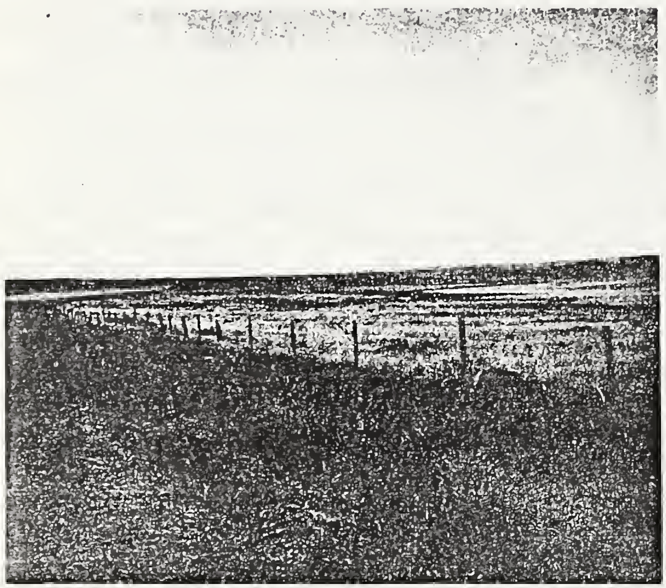


Figure 20: County Road, Whitewater North
The steep inslope, deep borrow area and sharp banks are doubly dangerous; the vegetation partially screens these hazards on this older county road.

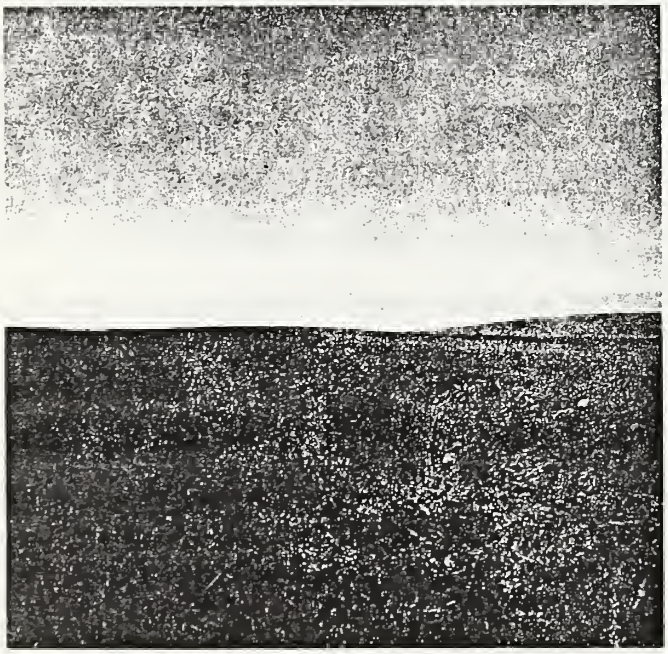


Figure 21: County Road, Whitewater North
The grades are normally built high to blow free of snow; this section is being regraded, thus removing hazardous backslopes (left center).

Since 1960, borrow pits have been built with inslopes graded 6 to 1 and the backslopes 3 to 1, wherever possible. This technique provides a less hazardous pathway for out-of-control vehicles, though the amount of right-of-way necessary for construction is greater.

This borrow pit design is used for all new projects, many of which are upgradings of old roads. In this manner, the unsafe borrow pits are gradually being eliminated, especially along state roads. County roads are being improved more slowly due to more limited availability of funds and lower traffic volumes.

VII. COUNTY RESPONSIBILITIES

Under state law the Boards of County Commissioners have the responsibility for selecting, planning, constructing and maintaining county roads. The Commissioners are also responsible for reseeding and establishing a permanent sod cover on all areas disturbed by county construction. Most recent county projects have been successfully revegetated. As in the case of state roads, a high percentage of the county roads were completed prior to mandatory reseeding. Some of these were revegetated through efforts at the local level, by natural means, while others remain unrevegetated.

VIII. RECOMMENDED LEGISLATION

The Montana Department is not requesting new legislation pertaining to seeding along highways. The Department finds that the present statute, while requiring the establishment of cover

on disturbed areas, is not so restrictive in that the flexibility necessary to handle a wide cross-section of conditions is lost. Construction specifications and special provision can be changed to reflect recent research developments and case by case problems while still satisfying the legislative intent.

However, a minor amendment could be instituted to clear up an interpretation problem regarding certification of seed. Section 2412 and 2814 of Title 32, R.C.M. (1947), call for seed meeting certified standards, and certified seed, respectively. Because of the various interpretations of "certified" or "certified standards," the Department feels that certifying agency should be defined as the Montana Department of Agriculture. The certifying agency should certify only the quality and purity (free of weed seeds).

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THE GREAT SEAL OF THE STATE OF MONTANA

ORO Y PLATA

ADDENDUM TO COOPERATIVE AGREEMENT ON IMPLEMENTATION
OF THE 208 PROGRAM IN THE STATE OF IDAHO
(Original Agreement dated 12/8/76)

Division of Environment
Idaho Department of Health and Welfare

Forest Service
U.S. Department of Agriculture

Whereas, the Forest Service and the Department mutually desire:

a. To develop and seek application of Best Management Practices (BMP's) for road activities through establishment of standard Best Management Practices, with the intent, to safeguard the quality of the waters of the State.

1. Therefore, it is mutually agreed:

   a. Application of the guidelines and methods set forth in IDHW-DOE's "Best Management Practices for Road Activities," as amended, (herein after called "BMP's-RA) shall be recognized as reasonable effort to satisfy nonpoint source control requirements of the Idaho Water Quality Standards (Section 1-2300.04).

   b. Application of USFS' internal rules and guidelines shall be recognized as reasonable effort to satisfy nonpoint source control requirements of the Idaho Water Quality standards (Section 1-2300.04) where such rules and guidelines comply with, or exceed, IDHW-DOE's "BMP's-RA) policy and guidelines.

   c. Where a new or experimental practice (not included in a. or b. above) is to be applied, USFS may either request IDHW-DOE approval prior to application or assume full responsibility for meeting Idaho Water Quality Standards through such practice application.

2. The Forest Service agrees:

   a. To apply guidelines and methods set forth in IDHW-DOE's in "BMP's-RA" location and design, construction, and maintenance of Forest roads.

   b. To protect the waters of the State for appropriate beneficial uses by the application of guidelines and methods in road design, construction, and maintenance set forth in IDHW-DOE's BMP's-RA or <u>apply methods</u> (1.c. above) <u>which demonstrates a knowledgeable and reasonable effort to minimize water quality impacts</u>.

3. The Department agrees:

   a. To revise individual elements of the guidelines, as necessary, only after consultation with the Forest Service on those changes.

b. To review the guidelines biannually with the Forest Service and revise as needed to maintain current, state-of-the-art BMP's.

IN WITNESS THEREOF, the parties hereto have caused this Addendum to the Cooperative Agreement to be executed.

IDAHO DEPARTMENT OF HEALTH AND WELFARE

Date 9-8-83 by: Rose Bowman [illegible]
Director

Date 9-9-83 by: [illegible]
Lee W. Stokes, Administrator
Division of Environment

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

Date 8/3/83 by: [illegible]
for J.S. Tixier
Regional Forester
Intermountain Region

Date 7/28/83 by: Tom Coston
Tom Coston
Regional Forester
Northern Region

WAL
Admin.

BEST MANAGEMENT PRACTICES

for

ROAD ACTIVITIES

Volume I:

location

construction

maintenance

design

Prepared by:
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Idaho Department of Lands
Idaho Transportation Department
Idaho Department of Water Resources
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Potlatch Corporation
Soil Conservation Service
U.S. Department of Agriculture - Forest Service Region 1
U.S. Department of Agriculture - Forest Service Region 4
U.S. Department of the Interior - Bureau of Land Management
U.S. Department of the Interior - Fish & Wildlife Service
U.S. Department of Transportation - Federal Highway Administration

FOREWORD

The primary goal of the Federal Clean Water Act (CWA) as amended in 1972 and 1977 is the attainment of fishable and swimmable waters by July 1, 1983. To meet this goal, the CWA authorizes the Governor of each state to designate agencies responsible for the development of water pollution control programs. In 1975, the Idaho Department of Health and Welfare was designated responsibility for statewide planning under Section 208 of the CWA. Although point sources of water pollution are controlled through the National Pollutant Discharge Elimination System (NPDES) permit program administered by the U.S. Environmental Protection Agency, non-point sources including runoff from construction activities are more difficult to identify and control. Therefore, the CWA requires that control strategies rather than discharge standards be developed for non-point sources. Section 208 (b) (2) (H) requires statewide designated agencies to develop "a process to (i) identify construction activity related sources of pollution and (ii) set forth procedures and methods (including land-use requirements) to control to the extent feasible such sources." It is under this directive that the Best Management Practices Handbook has been prepared by the Idaho Department of Health and Welfare.

Information contained herein supports the Idaho State Water Quality Standards by recommending and describing Best Management Practices (BMP's) as required for control of non-point sources of water pollution (Section 1 - 2300.04). Non-point activities lacking rules, regulations or guidelines are required to be conducted "in a manner that demonstrates knowledgeable and reasonable effort to minimize resulting adverse water quality impacts." The BMP Handbook will thus provide guidelines necessary to clarify non-point requirements applicable to road construction activities and serve as a basis for determining compliance with State Water Quality Standards. Secondarily, as various agencies have historically required differing degrees of erosion control, these BMP's will improve consistency of application among agencies involved in construction activities.

HOW TO USE THE HANDBOOK

This handbook is intended for statewide use by engineers, designers, private developers and other personnel involved in road location, design, construction, and maintenance operations. Best management practices which protect road stability, soil productivity, and water quality are presented sequentially to coincide with various phases of road construction. Stepwise considerations for selecting protective measures focus primarily on minimizing erosional impacts of roads. It is vital that personnel engaged in road building activities are aware of the basic principles of erosion and sediment control and understand how these principles can be used in the construction of stable roads. However, other problematic sources such as waste disposal and use of pesticides, fertilizers, and chemical deicers are also discussed with respect to the appropriate road phase.

The term "best management practice" refers to a practice or combination of practices determined by a designated 208 planning authority after problem assessment, evaluation of alternative practices and appropriate public participation to be the most effective and practicable means of preventing or reducing the amount of water pollution generated by non-point sources to a level compatible with water quality goals. Best management practice guidelines have been written to afford design flexibility and to accomodate a wide variety of road types ranging from access roads (mining, forest, agriculture, residential) to major highways. The user of this handbook should recognize that not all best management practices will apply to a given site. Rather, brief details are described for each protective measure as an aid to selection based on guideline statements and assessment of site-specific conditions.

Where additional, technical, or legal information is desired, the reference appendix provides a directory of Soil Conservation District and Soil Conservation Service offices for obtaining local soils data, a listing of current research agencies and copies of applicable state legislation.

Volume II of the handbook presents detailed information on specific Best Management Practices. Although, there may be several equally effective alternatives, these practices may be unequal in cost, time of implementation, or permanency. Each practice included in the BMP Summary Chart (Volume I) is, therefore, followed up with corresponding information relative to applicability, design criteria, maintenance, and effectiveness for comparison in selecting the most appropriate alternative.

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SECTION I

IDENTIFYING THE NEED FOR BMP'S

IDENTIFYING THE NEED FOR BMP'S

NATURAL EROSION PROCESSES

Soil erosion occurs when soil particles are detached and transported by water, wind, and/or gravity. The process by which soil particles are redeposited is referred to as "sedimentation".

Water. Most often erosion is caused by raindrop impact or concentrated runoff (rainfall or snowmelt) on denuded or unstable soils.

Wind. Wind velocities of 8 - 9 mph (12.9 - 14.5 km/h) 6 inches above dry ground are sufficient to move soil particles.[1]

Gravity. When gravitational forces overcome the natural resistance of a soil mass, "mass wasting" is likely to occur.

Water caused erosion may be evident in three primary forms, listed here in order of increasing severity.

- Sheet erosion; removal of thin layers of soil caused by sheet flow across a fairly uniform surface.
- Rill erosion; formation of small channels due to concentrated or repeated runoff, usually obvious 8 - 10' below top of fill slopes.[2]
- Gully erosion; formation of deep channels due to concentrated or high velocity runoff.

Wind caused erosion may account for substantial soil loss in arid regions. Fine silt and clay particles are blown away as fugitive dust and the heavier particles are moved in a series of leaps known as "saltation". Wind erosion is probably most easily confirmed by actual observation of blowing dust particles.

Gravity caused erosion is evident in two primary forms: 1) deep, rotational soil movements including slumps, earthflows and landslides and, 2) shallow debris movements including rockslides, debris avalanches, and debris flows (more common in forested mountain areas). These forms of erosion cause the most sudden damage because large volumes of material are released and may be concentrated at specific points in stream channels.

Research indicates that slopes greater than 55% tend towards instability and the chance of mass failure.[3] Debris movement is likely to develop suddenly in bedded sediments or on shallow, relatively coarse-textured, cohesionless soils on steep hillsides. They are characterized by rapid downslope movement of fractured rock, soil and organic material along a slip surface roughly parallel to the topographic surface. Rotational slumps, earthflows, or soil creep are likely to proceed in deep, saturated, fine textured soils on more moderate slopes and normally extend over a smaller area. Slumps and earthflows are relatively fast moving but are often preceded by soil creep which gradually changes the balance of forces on a slope. Soil creep may be on the order of less than one foot per decade, however, stresses in potential slumps may build to the extent that even moderate rainfall may trigger an earthflow.

Signs of impending slope failure include:

- sagging of cutbank, subgrade, or fill
- trees that tip or lean
- appearance of new or accelerated ground water discharge from cutbanks, and
- standing water in ditches.

ROAD RELATED EFFECTS

Although erosional processes are natural and continuous, erosional rates may be greatly accelerated by certain road activities.

Excavation - exposes additional soil surface area to erosive forces
- loosens soil structure, making soil more susceptible to detachment

Vegetative Clearing - exposes additional soil surface area to erosive forces
- loosens soil structure, through root removal/decay, making soil more susceptible to detachment
- increases runoff volume and velocity by reducing interception and losses to evapotranspiration

Grade Change - (side slopes and road surface) upsets natural drainage patterns
- increases flow velocity or concentrates flow volume at undesirable locations

Compaction - increases runoff by reducing infiltrative capacity of soil
- upsets natural drainage patterns

Drainage System - concentrates runoff flow and increases erosive velocities
- installation loosens soils, making them more susceptible to erosion

Debris Disposal - increases gravitational force on supporting ground
- increases potential for debris avalanches and debris flow.

OVERALL WATER QUALITY IMPACTS

Erosion and subsequent sediment movement into lakes, streams, and reservoirs can adversely impact water quality, fish and wildlife habitat, downstream property, vehicle maintenance, road maintenance, and road safety. In addition, sediment laden runoff can pick up and transport other potential pollutants associated with road activity including pesticides (insecticides, fungicides, herbicides), petrochemicals and heavy metals (oil, gasoline, asphalts), construction chemicals (acids, soil additives, concrete curing compounds), wastewater (aggregate washwater, pesticide rinsate, concrete cooling water, clean-up from concrete mixers), lime and fertilizers. The severity of the resulting water quality impacts depends on the quantity of sediment and other pollutants reaching natural waterbodies and the existing quality of the receiving water.

Sediment suspended in streamflow can disrupt aquatic ecosystems in several ways. Reduced light penetration inhibits photosynthetic plant growth and the ability of sight-feeding organisms to locate food sources. Most fish have a temporary response mechanism that flushes sediment from their gills. However, fish subjected to sudden and prolonged sediment increases may experience gill clogging and gill abrasion, eventually leading to fatal stress. Spawning gravels are often ruined as they become covered with deposited sediment. Downstream sediment damages include lowered reservoir and channel capacities due to bottom-filling with sediment. Treatment costs for municipal and industrial water supplies may be increased by the operation of additional equipment for sediment removal. Power generating turbines may be damaged by the abrasive action of sediment. Flood damage may occur where severe erosion deposits large quantities of sediment and debris in drainageways, causing plugging and structural washouts.

Road surface contaminants and materials stored, applied or disposed of on site can also pollute waterbodies when transported by runoff water or adherance to sediment suspended in runoff water. Fuel and oil residues contain lead and other heavy metals which are toxic to humans in small concentrations. Recent research studies of highway runoff constituents have consistently found cadmium, copper, lead, and zinc concentrations at levels exceeding EPA toxicity criteria. Metals can be generally characterized by having low water solubilities and thus eventually deposit among receiving water sediments. Only the dissolved ionic forms are highly toxic. Very young or unhealthy aquatic organisms are most vulnerable to acute or chronic exposure.

Certain pesticides also contain highly toxic chemicals which may persist a long time in soil and water and be passed along plant and animal food chains. Nitrogen and phosphorus compounds used in fertilizers stimulate aquatic plant growth causing algal blooms and noxious conditions. (Phosphate additives are also used as corrosion inhibitors in deicing chemicals.) Cyanide complexes (anticaking agents) and chromates (corrosion inhibiting agents) are added to deicing compounds and in small concentrations are sufficient to cause rejection of public water supplies and death of aquatic organisms. Runoff of road salts onto adjacent soils decreases soil fertility, soil structure, and plant water uptake, causing leave burn and dessication. These salting effects result in vegetation loss and thereby allow runoff and sediment to leave the roadway more freely.

SECTION 2

APPROACH IN SELECTING BMP'S

APPROACH IN SELECTING BMP'S

BASIS FOR CONTROL

Erosion control methods are selected to minimize soil movement by limiting soil disturbance and exposure, controlling slope gradients to reduce runoff volumes/velocities and providing adequate drainage to protect road surface, side slopes, and borrow areas. Sediment control measures are based upon interception and detention of sediment laden runoff and removal of soil particles by filtering or settling. These measures are intended to protect downstream water quality and adjacent properties from sediment damage. Both types of controls can be either temporary or permanent. Temporary methods are often installed before or during construction and remain in place until permanent methods become effective. For example, sediment basins may be required to collect additional sediment generated during excavation operations but following road completion, revegetated slopes and controlled drainage may provide the necessary degree of control.

Because sedimentation follows erosion, methods to control both processes are primarily directed towards erosion control, with sediment controls functioning as a back-up system. In general, selection of controls will be based upon the cause and extent of soil movement (described in the previous chapter) and site specific factors or activities influencing erosional rates. This chapter proceeds to discuss sequential considerations in developing, installing, and maintaining effective erosion controls throughout various road project phases and following road closure.

LOCATION AND DESIGN

Many erosional problems can be avoided during road construction if anticipated and prepared for in advance. Control needs are therefore determined during location and incorporated into overall road design specifications to ensure timely application and proper construction.

The first step in assessing control needs is to gather data regarding site factors influencing soil erodibility or "erosion potential". The most stable route location can then be chosen by comparing field data collected at each alternative and incorporating field conditions into erosion prediction equations.*

<u>Soil</u>; samples should be collected and analyzed for mechanical and chemical properties. Soil type and texture influences compaction, infiltrative capacity, resistance to erosion by particle size, and vegetative suitability. Soil survey data is often available from local Soil Conservation District or Service offices (see Appendix I for location of Idaho offices).

<u>Climate</u>; influences soil infiltrative capacity, soil cohesion, and runoff conditions. Verification of total annual rainfall, storm/flood frequency

* Reference for further information on soil loss equation: Wischmeier, W & DD Smith, 1978. <u>Predicting Rainfall Erosion Losses - A Guide To Conservation Planning</u>, USDA Handbook.

and seasonal temperature extremes is vital to the efficient design of drainage control structures and proper timing for installation. If rainfall and snowmelt exceed soil infiltration rates, overland flow and erosion occur. Collection and dispersion systems for runoff should be integrated to prevent erosion of fill, travelways, natural slopes, or below drainage structures.

Topography; influences runoff patterns and conditions. Slope length, gradient and the size of the drainage area above the site are of particular importance in controlling runoff volumes and velocities.

Geology; should be investigated to locate unstable areas and possibly sources of subgrade materials. Geotechnical surveys may be helpful in detecting fault zones or fractures which predispose an area to mass failure.

Elevation and Aspect; influences runoff conditions and exposure of soil to weathering forces. Midslope roads are afforded better drainage than flat surfaces or slope toe locations. South and west facing aspects are more susceptible to erosion than north and east facing slopes.

Locations near critically erodible or environmentally sensitive areas including natural drainageways, lakes, ponds, springs, windy areas, high water tables, floodplains, and wetland should be avoided. The Idaho Batholith (Figure 1) is characterized by shallow, coarse textured soils overlying steep, heavily forested areas where timber harvest and forest maintenance involve annual road building.[4] In such areas where critical soils cannot be avoided, location may rely heavily on elevation and aspect. The major problem associated with road construction on steep granitic soils is stabilizing fills with regard to both surface and mass erosion. To minimize the possibility of mass wasting, location and design should avoid:

- streamside location
- landslide areas
- overconstruction (reduce width, roll grades)
- tension cracks
- high cut embankments
- narrow canyons (where excavation will remove support from the base of the fill).

Special site factors to consider in evaluating potential mass failure areas include:

- resistance of rock
- slope of bedding planes relative to ground slope
- groundwater conditions (control drainage at base of fills)
- faults and geology (suspected zones may be indicated by saddle and ridge alignment and direction of streamflow).

Once erosion potential for the most stable route has been established, control methods can be selected and designed to accomodate anticipated runoff and sediment volumes. The best management practice summary[5], contained in this handbook, provides a useful reference for choosing controls by grouping methods into five functional categories as follows:

1) General (i.e. timing of application, surface area exposure)
2) Surface Stabilization

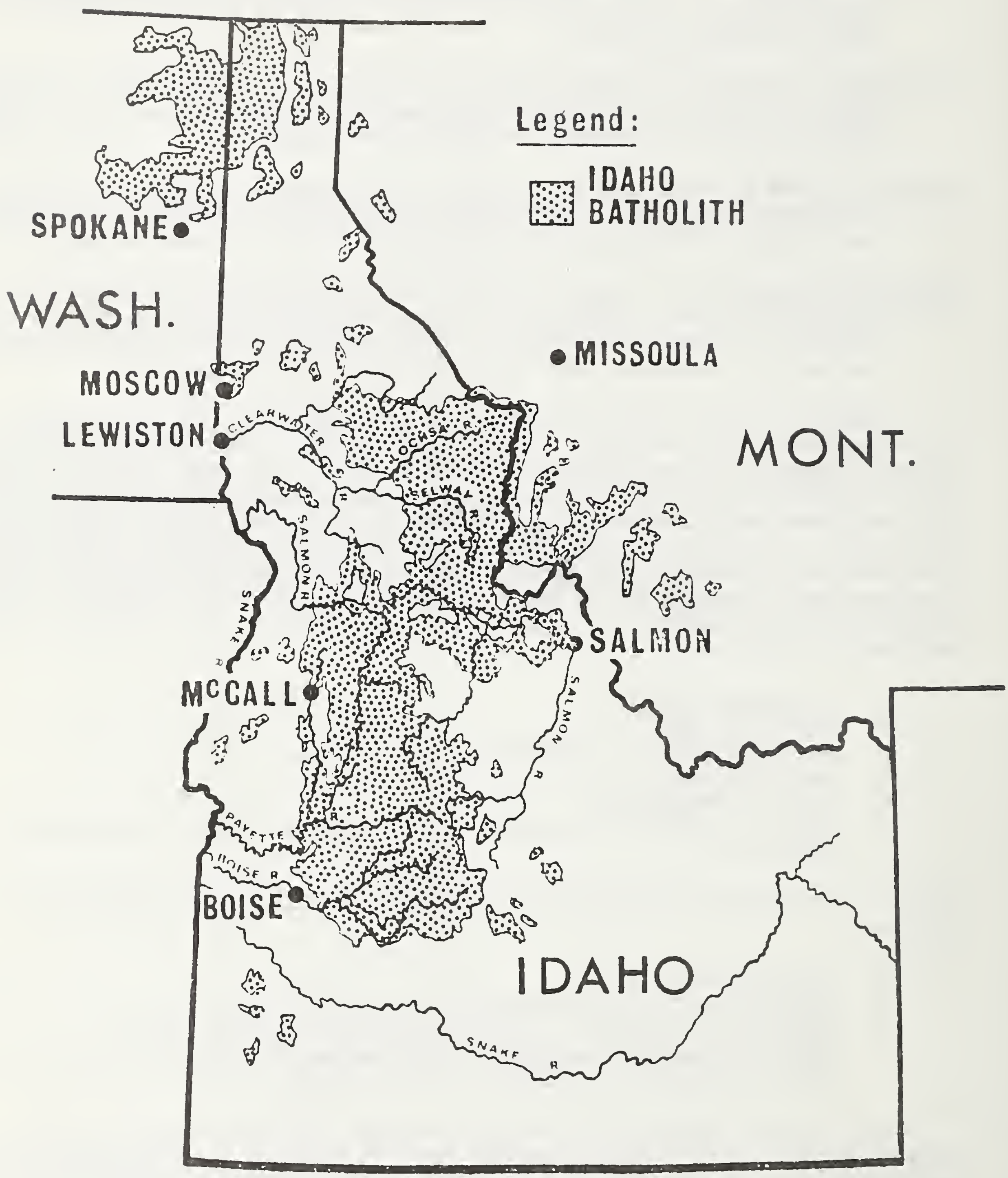

Figure 1: LOCATION OF IDAHO BATHOLITH H

3) Runoff Collection and Conveyance
4) Runoff Dispersion
5) Sediment Collection

Although several methods may apply to a given situation, the final design proposal must satisfy engineering feasibility, financial, economic, sociological, legal, and environmental criteria. Conducting an interdisciplinary design review may be desirable to assure these criteria receive equal attention. Designers, engineers, and maintenance personnel should consult with soil scientists, hydrologists, geologists, agronomists, landscape architects and other specialists as needed.

DESIGN REVIEW

An interagency review of road plans allows for additional input from appropriate specialists, broadens identification of anticipated social, economic, and environmental concerns and ensures consistency among goals and objectives of State, areawide, and local planning. The National Environmental Policy Act of 1966 (NEPA) requires an interdisciplinary review of all plans proposed under Federal funding. Agencies wishing to submit comments may do so through the Idaho State Clearinghouse A-95 review process.

Local planning agencies and private individuals who have no formal review requirements may find the following checklist useful.

- Has a soil survey been conducted to assess soil properties and erosion potential?
- Has hydrologic data been collected to evaluate existing drainage patterns and runoff conditions?
- What erosion control and sediment collection measures are required before cleaning and other work is started?
- Has work been scheduled to minimize the amount of disturbed area?
- Has erosion potential been considered for each alignment alternative?
- How will existing and future uses of adjacent waterbodies or wetlands be affected?
- Will special erosion control and sediment collection measures be required to protect adjacent property?
- Can sediment from construction activities be collected on or near the project?
- Should additional right of way or easements be provided to permit sediment allocation?
- What effect will construction sequence, method of operations or season of work have on control measures?
- Have erosion and sediment controls been identified on the plans and provided in the contract?

- Are provisions included for maintenance activities including sediment removal and disposal?

- Are provisions included for evaluating effectiveness of control practices?

- Has a design review been established to review project design, including erosion and sediment control measures?

- Are there utilities, other agencies, or private companies that should participate in the plan review?

CONSTRUCTION

Because the effectiveness of a particular method depends a great deal on proper design, placement, and timing of application relative to the construction period, detailed plans for erosion and sedimentation control should be included in road design specifications prior to actual construction. Although construction is normally scheduled during periods of low runoff and curtailed in winter, unanticipated storm events may cause extensive damage if drainage facilities and surface protection are not installed and maintained as work is completed. A typical flow diagram illustrates the timing of erosion and sediment control applications relative to construction progress (Figure 2).[6]

During construction, special attention should be directed towards:

1) Providing early drainage and sediment collection systems.

   Drainage diversions and sediment collection systems should be installed before earth moving activities begin. In this way, diverted water is protected from sediments generated by earth moving and adjacent property is protected by the on site sediment collection system.

2) Re-establishing vegetative cover.

   Vegetation is generally the most effective method of stabilizing exposed soils outside the right of way. It often takes 2 - 3 years for vegetation (seeding) to establish and become fully effective, therefore temporary methods are normally used in conjunction with staged seeding during this interim period. Vegetation may not be the most effective stabilizer in areas of slope greater than 3:1, depending on climate and rainfall concentrations, (Figure 3).[7] However, deep rooted vegetation has been demonstrated to be effective in stabilizing shallow, granitic soils on steep slopes.[8] Such areas may be enhanced for vegetative success by serrated cuts or use of mulch tackifier to hold seeds in place. Stripping and replacing of topsoil aids vegetative re-establishment and may alleviate the need for transporting additional fertilizer or topsoil.

3) Controlling runoff volume, velocity, and concentration.

   Drainage facilities should be installed to protect work as it is completed. Drainage outlets must be to stable areas and protected to prevent undercutting at outfalls. Most commonly riprap is used for this purpose. Similarly stream channel work and culvert installations must avoid flow constriction and subsequent velocity increases which may accelerate streambed erosion.

4) Routine inspection and cleaning of erosion and sediment control features.

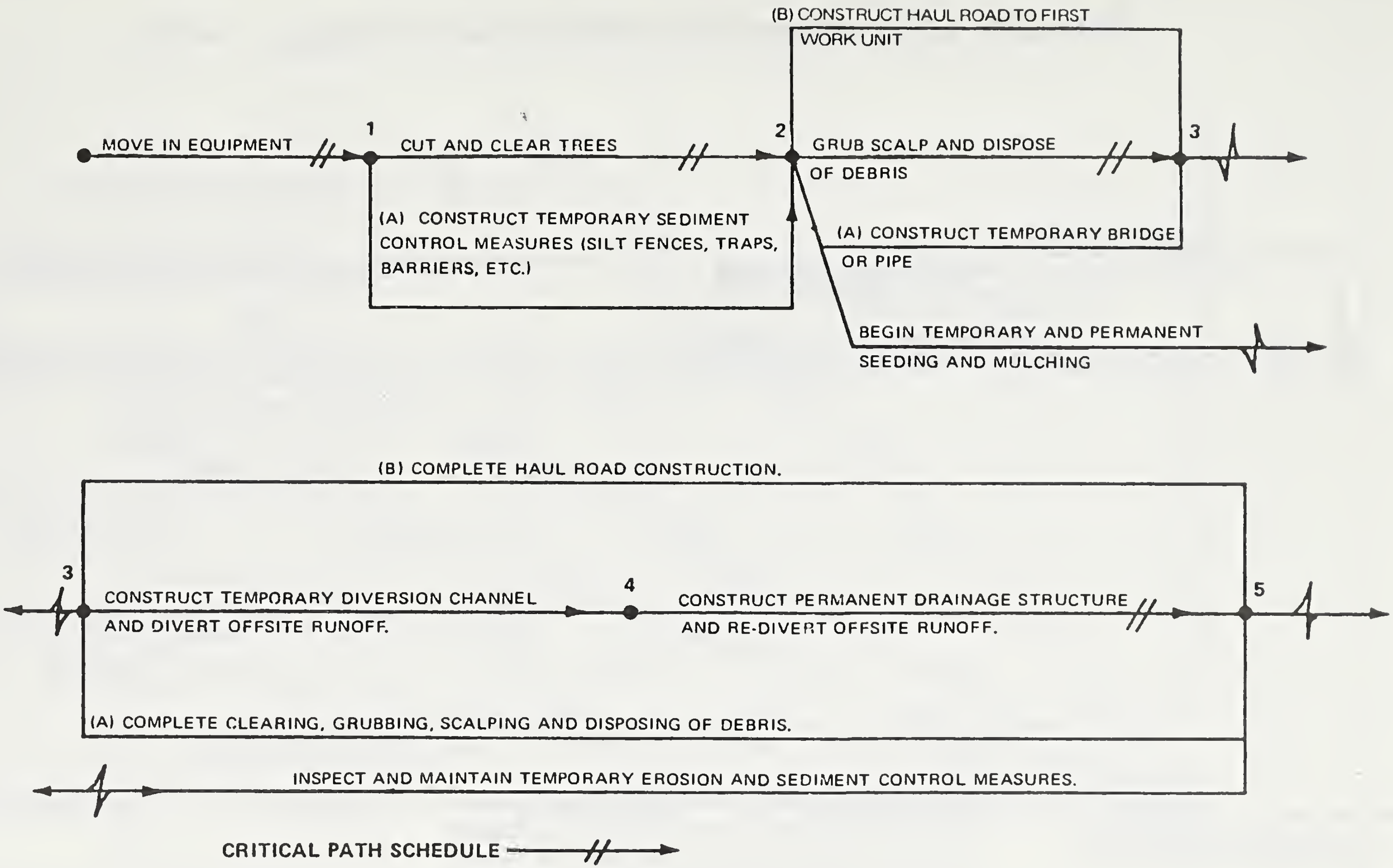

Figure 2: **TYPICAL FLOW DIAGRAM FOR CONSTRUCTION ACTIVITIES**

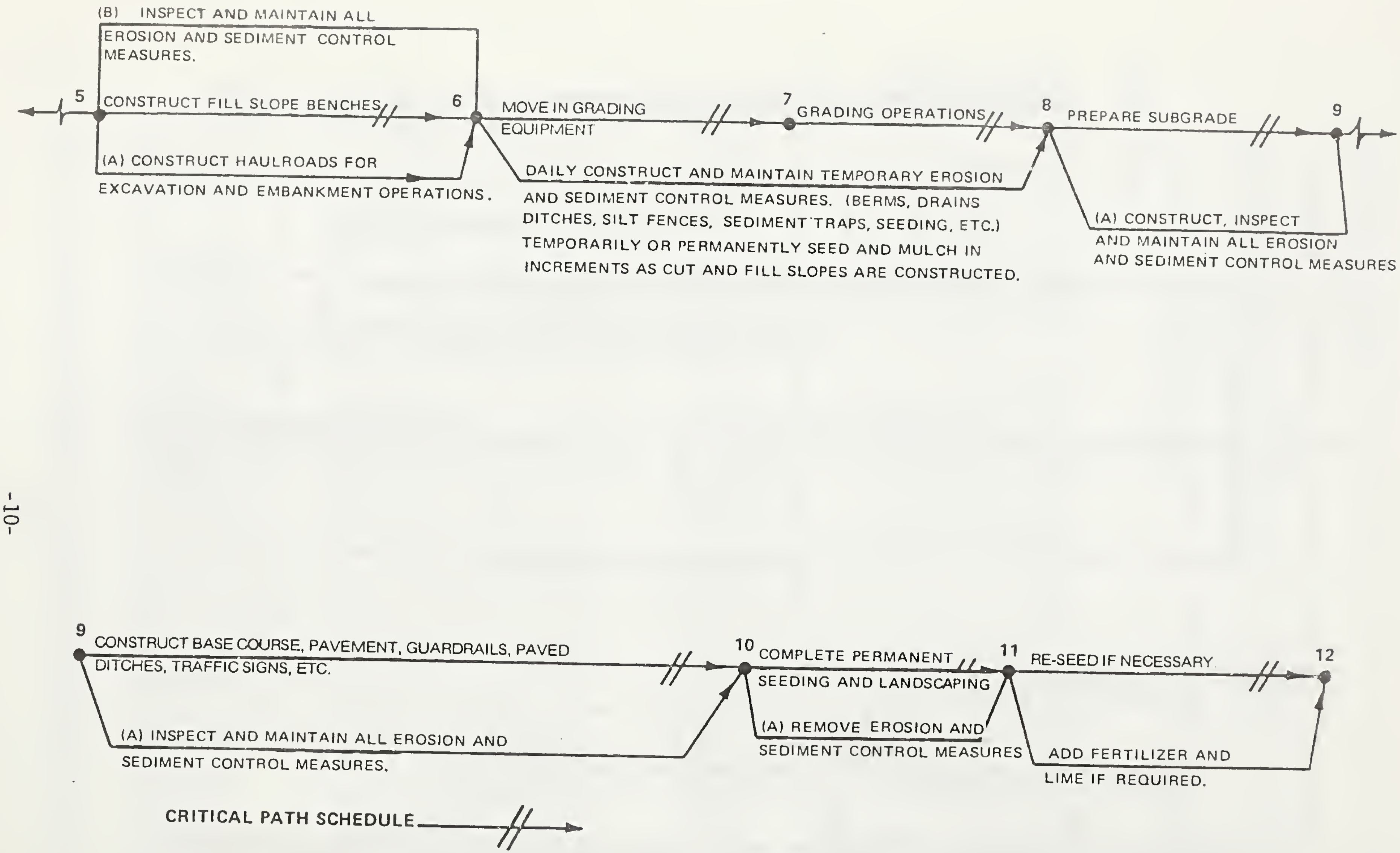

Figure 2: **TYPICAL FLOW DIAGRAM FOR CONSTRUCTION ACTIVITIES**

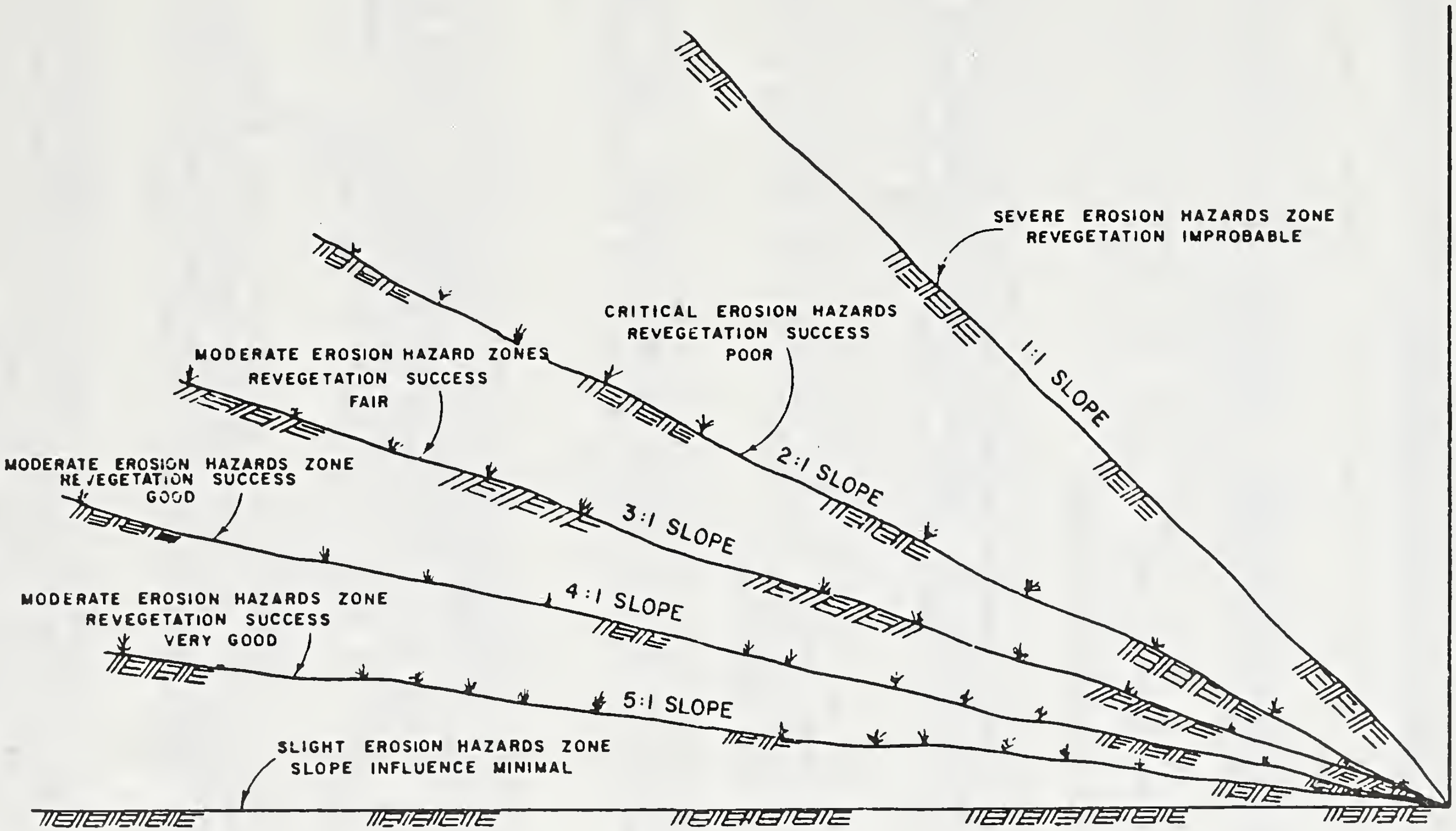

Figure 3: INCREASING DIFFICULTY OF ESTABLISHING VEGETATION

Inspection is especially important after periods of high runoff to detect structural damage. Drainageways and sediment collection systems should be inspected and cleaned regularly of accumulated debris and sediment to prevent plugging, flooding or structural washouts.

5) Minimizing soil exposure during earthwork operations (i.e. clearing, stripping, excavation, subgrade preparation).

By limiting soil exposure, the amount of soil subjected to erosive forces is also limited.

6) Proper final grading and embankment construction (i.e. slope and ditch rounding, feathering cuts, blending cut and fill).

Final construction contours should blend with surrounding topography to maintain natural drainage patterns where possible.

7) Safe material storage and disposal.

Construction materials (including chemicals) and debris should be stored and disposed of in areas where movement into watercourses is unlikely. However, stockpiled debris is sometimes placed in drainageways to serve as such erosion and sediment control as brush filters and debris check dams.

In potential mass wasting areas, sidecasting of excavated material should be avoided on steep slopes. If flat slopes are not available, materials should be transported to a safe disposal site to avoid slope overloading and possible slope failure.

Stockpiled topsoil should be protected by suitable cover (revegetation, plastic sheeting) or berms to control sediment movement. Berms should also be used around chemical or fuel storage sites to contain spills.

MAINTENANCE

Road maintenance activities relative to erosion and sediment control focus on routine cleaning of drainageways and sediment collection systems to remove debris and prevent flooding. In addition, cleaning operations should follow major storms where greater flows and sediment may cause structural damage or decreased capacity. Inspections of revegetation efforts should be conducted annually until stabilized to determine the need for supplementary seed or fertilizer application.

During routine road maintenance such as repaving, surface grading or recompaction, care should be taken to avoid disturbing roadside vegetation or allowing sediment to enter waterways. Care also should be taken to avoid instability problems caused by undercutting sideslopes or sidecasting materials onto steep fill slopes.

The use of oil or deicing salts for seasonal maintenance should be avoided near waterways. Sand is preferred where application is in close proximity to waterbodies. Snow removed from roads often contains chloride from road salt applications and lead pollutants from fuel and oil residues. Therefore, disposal of snow directly into waterways should be avoided.

ROAD CLOSURE

This section applies mainly to permanent closure of unpaved roads. Specific procedures for closure are highly variable but all are intended to return the site to as natural a state as possible with minimal soil or drainage disturbance. Relative to erosion and sediment control, the right-of-way should be stabilized by revegetation and self-maintaining drainage systems (i.e.; cross drains, water bars).

When structural features such as bridges or culverts are removed, soil disturbance should be minimized and all debris should be removed within 50' of drainageways to prevent clogging or flooding. Fill material should also be removed from below the high water mark and placed in safe disposal areas. The remaining fill should be left at a stable angle.

It may be desirable to break surface compaction to enhance revegetation efforts and to remove berms or break them at frequent intervals to aid lateral drainage. Berms should be left on all deep fills and climbing roads except at drainage outlets.

A special technique referred to as the "Kaniksu Closure" was developed in northern Idaho for use on slopes up to 60%. This technique involves removing the outer berm and part of the fill and placing the excavated material in the road cut area. This procedure minimizes additional soil disturbance and replaces soil at nearly the original slope (see Figure 4).

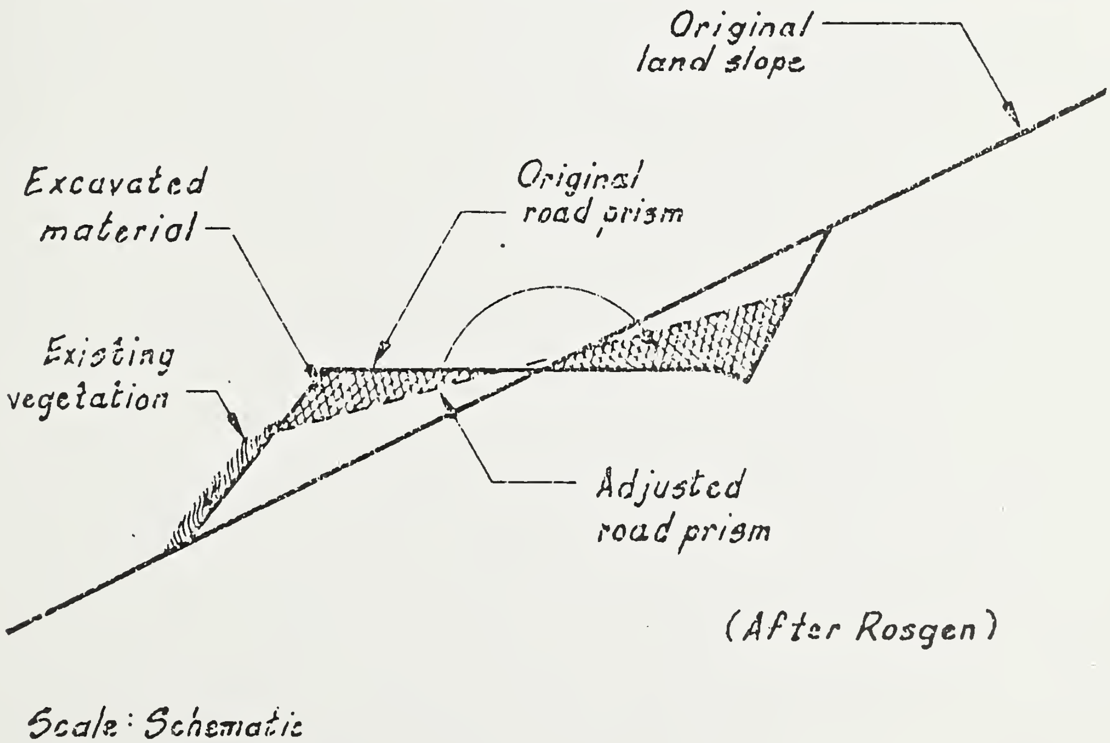

Figure 4: KANIKSU CLOSURE

SECTION 3

BEST MANAGEMENT PRACTICES

BEST MANAGEMENT PRACTICES

BMP POLICY

Recognizing that sediment is the primary pollutant in surface waters and that land disturbances created during road activities may greatly accelerate erosion and sediment production, and also recognizing that waste materials or chemical treatments associated with roads are susceptible to runoff into surface waters, it is the policy of the Idaho Department of Health and Welfare to protect waters of the State from all road generated pollutants through recommending application of the Best Management Practices contained herein.

BMP POLICY GUIDELINES

Location and Design

1) Reuse of existing roads should be favored over construction of new roads when reuse or reconstruction would result in less adverse long term environmental impacts.

2) Roads should be designed no wider than necessary to accomodate safe use and planned drainage facilities.

3) Road plans should include provisions for erosion control and ensure availability of materials for installation of temporary and emergency erosion control measures.

4) Road cross sections should be planned to control runoff and minimize erosion.

5) Cross drainage installation should be at a minimum slope of 1% to avoid plugging.

6) Cut and fill slopes should be designed to fit natural topography and avoid instability.

7) Areas of vegetation between roads and waterbodies should be left or re-established to serve as buffer strips.

8) Roads should be located and designed to minimize encroachments on streams.

9) Stream crossings should minimize disturbance to streambanks and channels and be planned in compliance with minimum standards for stream alterations under provisions of Title 42, Chapter 38, Idaho Code (see Appendix III).

10) All culverts and bridges should be designed to accomodate acceptable design flows and provide for fish passage where appropriate.

11) Drainage structures for access and haul roads having projected lives of greater than one year, should be capable of accomodating acceptable design floods and provided with inlet and outlet protection.

Construction

1) All construction should be performed in accordance with design specifications which include provisions for erosion control.

2) Construction work should be scheduled to limit exposure of unprotected soil surfaces to the work area required for seasonal construction operations.

3) Excavation should be postponed during periods of heavy rainfall or snowmelt unless materials can be placed and stabilized as designed.

4) Erosion and sediment control measures should be installed at the earliest practicable time and be coordinated to assure economical, effective and continuous control throughout the construction and post-construction phases.

5) Erosion control plans should ensure that materials for installation of temporary and emergency erosion control measures are readily available.

6) Existing roadside vegetation should be protected where possible during construction.

7) Potentially unstable and erodible areas should be stabilized by use of seeding, compacting, rip-rapping, benching, mulching, or other suitable means.

8) Incorporation of snow, ice, frozen soil, or loose organic materials buried in embankments should be avoided.

9) Stream channel crossings should be constructed to minimize disturbance to streambanks and channels and avoid entry of sediments into waterways.

10) Drainageways should be cleared of all debris generated during construction and maintenance to prevent obstruction of flow and adverse water quality impacts.

11) Water pumped from foundation excavation should not be discharged directly into streams, but should be pumped into settling areas.

12) Washwater or waste from concrete batching or aggregate operations should not be allowed to enter streams prior to treatment by filtration, flocculation, settling, or other means of clarification.

13) Removal of water from a natural waterbody for use in construction and maintenance activities should be conducted to prevent erosion and adverse water quality impacts.

14) Borrow and stockpile areas should be selectively located and protected from wind or water erosion.

15) Established vehicle service and refueling areas and chemical storage sites should be located away from wet areas and watercourses, using berms and dikes to contain spills around such sites.

Maintenance

1) Maintenance activities should be sufficient to keep drainage systems operating and protect the quality of adjacent waterbodies.

2) All erosive slopes should be stabilized where practical.

3) During maintenance operations, care should be taken not to undercut slopes or excessively blade vegetated or stabilized slopes.

4) Grading should be conducted in a manner that prevents entry of sediment into waterbodies.

5) Debris or slide materials associated with maintenance operations should not be deposited in waterways but rather should be placed in stable areas with adequate buffering between waste areas and adjacent waterbodies.

6) Established vehicle service and refueling areas and chemical storage sites should be located away from wet areas and watercourses, using berms and dikes to contain spills around such sites.

7) Dust pallatives, fertilizers, deicing salts, or other chemicals should be stored and applied to minimize intrusion of such chemicals into surface runoff or waterways.

8) During snowplowing operations, care should be taken not to damage the road surface or undercut slopes and avoid entry of road surface materials into waterways.

9) Breaks in snow berms should be provided to allow adequate road surface drainage and prevent erosion during snowmelt.

10) All unpaved roads open to use should have drainageways cleaned and road surface crown, inslope and outslope restored prior to periods of high runoff or seasonal closure.

11) Where serious erosional problems exist due to ineffective controls or lack of maintenance, roads should be temporarily closed until corrective action can be taken.

12) Following permanent road closure, roads should be blocked to vehicular traffic and left in a state that provides adequate drainage and soil stabilization.

13) Following permanent road closure, culverts should be removed where mass failure hazards exist.

14) Where bridges are removed following permanent road closure, abutments should be left to protect streambanks.

15) Removal of water from a natural waterbody for use in construction and maintenance activities should be conducted to prevent erosion and adverse water quality impacts.

SUMMARY OF BEST MANAGEMENT PRACTICES FOR EROSION AND SEDIMENT CONTROL ON ROAD PROJECTS

The chart appearing in this section briefly describes acceptable methods for erosion and sediment control on road projects. Methods are grouped into five categories based on their intended function. These categories are:

General (i.e. timing of application, surface area exposure)

Surface Stabilization

Runoff Collection and Conveyance

Runoff Dispersion and

Sediment Collection

This chart has been included to give the reader some idea of the diversity of available control methods.* Those who desire more in-depth information on a particular method, should refer to Volume II of this handbook (see far right hand column for locating corresponding information in Volume II). Volume II details definition, purpose, applicability, planning criteria, methods and materials, maintenance and effectiveness for each control method.

* The inclusion of specific trade names or products in this chart in no way reflects IDHW endorsement of these materials or their effectiveness.

TYPE OF CONTROL MEASURE	CHARACTERISTICS OF MEASURE AND SPECIAL CONSIDERATIONS*	Adjacent Properties	Adjacent Water Bodies	Borrow and Stockpile Areas	Enclosed Drainage (Inlet and Outlet Control)	Large Flat Surface Areas	Medians	Protection From Wind Erosion	Rights of Way	Shoulders	Slopes (Cuts and Fills)	Streams and Waterways	Surface Drainageways	Reference Number (volume II)
GENERAL														
Irrigation	For the purpose of establishing and maintaining vegetation. Water is generally most efficiently applied by sprinkler or drip irrigation.			X		X	X	X	X	X	X			II-10
Timing of Control Implementation	An excellent erosion control measure is of no value until it is implemented. Therefore, erosion control measures should be implemented at the proper time and place to be of maximum benefit.	X	X	X	X	X	X	X	X	X	X	X	X	I-24
Stripping and Replacing of Topsoil	Stockpiling and subsequent spreading of topsoil on cut and fill slopes aid in the establishment of vegetation by supplying needed fertility and native seeds. Soil should have a chemical and mechanical analysis prior to stockpiling. Organic content is less important than texture. Higher sand content tends toward droughty conditions and high clay content limits aeration and drainage. *Both downstream areas and the stockpile should be protected using such things as berms, temporary filter strips and protective covers (plastic sheeting, vegetation).					X			X		X			II-11
Surface Area Exposure	The smaller the area exposed to the elements at a time with no protection, the less will be the erosion from that site. Good management will ensure the cleared areas have erosion control measures installed before additional areas are bared.	X		X		X	X	X	X	X	X	X		I-25
SOIL STABILIZATION														
Aggregate cover	Made by placing gravel on soil surface. May be used as permanent part of base construction. Permits construction traffic in adverse weather. Used on seeps. *Requires reworking or compaction if exposed for long periods of time.				X	X	X	X		X	X	X	X	- - -
Cellular Concrete Block Revetment (Gobi Blocks)	These blocks are contructed of dense concrete and are installed on top of a plastic filter cloth. After installation, topsoil is spread loosely over the revetment to partially fill the cell openings, and the revetment is then fertilized and seeded.		X		X			X			X	X	X	I-1
Chemical Stabilization Aerospray 52 Aerospray 70 Aquatain Arzan Asphalt Emulsion Coherex Conwed Fiber Curasol Dust Binder Ecology Control Erode-X Fiber Glass Roving, Tacked Glenkote Petroset PVA Soil Bond Soil Lok Soil Master Soil Seal Surfaseal Terra-Krete Verdyol (Super) Wood Fiber Slurry	Chemical binders or tacks include latex emulsion, plastic film, resin-in-water emulsion, or similar products which are usually sprayed over bare soil or mulch to bind soil particles or mulch material, reduce soil or moisture loss and enhance plant growth. Binders and tacks temporarily stabilize soil against wind and water erosion until vegetation becomes established. They may be applied with seed, lime and fertilizers on any disturbed area. *Particularly useful in arid regions to prevent wind erosion. Care must be taken to prevent entry into waterbodies.				X		X	X	X	X	X		X	I-1

TYPE OF CONTROL MEASURE	CHARACTERISTICS OF MEASURE AND SPECIAL CONSIDERATIONS*	Adjacent Properties	Adjacent Water Bodies	Borrow and Stockpile Areas	Enclosed Drainage (Inlet and Outlet Control)	Large Flat Surface Areas	Medians	Protection From Wind Erosion	Rights of Way	Shoulders	Slopes (Cuts and Fills)	Streams and Waterways	Surface Drainageways	Reference Number (volume II)
		WHERE MEASURE IS USED												
Compaction	Proper compaction of fill embankments is especially effective at low velocities. It should be done in proper increments at the optimum soil moisture content.								X		X			I-14
Fertilization	Applied according to soil vegetation needs as determined by testing. Stimulates growth which increases erosion resistance. Fertilization should be part of initial seedbed preparation, however, supplement applications may be necessary as part of maintenance where growth is slow. *Care should be taken to prevent entry into adjacent waterbodies.			X		X	X			X	X		X	II-9
Gabions	Contruction of gabions is accomplished by placing wire-mesh baskets at the desired location, filling them with gravel or rocks and tying them together. Sizing of gravel or rock will depend on amount of protection required. The filtering effectiveness of rock-filled gabions has been observed to approximately double when 1" of compressed straw is placed in the bottom of the gabion. *Gabions must be properly placed and keyed to slopes to prevent undercutting.	X			X						X	X	X	I-15
Gobi Blocks (See Cellular Revetment)														
Grubbing Omitted	When grubbing is omitted, the surface algae as well as vegetation grow and stabilize the soil. Established root systems also are left to hinder erosion. New sprouts will occur more rapidly and fertilization may not be needed.							X	X					- - -
Matting Excelsior Jute Plastic	Mats must contact soil fairly uniformly and may not be suitable on irregular surfaces. Jute matting should be overlapped to allow for shifting. *Will not withstand medium to high velocities.	X			X	X	X	X		X	X		X	I-2--5
Mulch Cellulose Dairy Waste Gravel Hay Hydromulch Rice Hulls Sawdust Shredded Paper Straw Vegetative Fodder Wood Chips Wood Fiber Other	Mulch material is applied to surface to temporarily stabilize soil and aid vegetative growth. Purpose of seedbed application is to conserve soil moisture, insulate against solar radiation and wind and reduce impact of water runoff. May be used in place of chemical stabilizers to protect against erosion during delays in grading or revegetation. *Proper application rates are essential to effectiveness. Will not withstand medium to high velocities.	X		X		X	X	X	X	X	X			I-6--11
Mulch Anchoring Asphalt Tacking Matting Netting Punching	Anchoring increases the effectiveness of mulch against surface erosion by wind and water. It is accomplished by spraying (asphaltic materials), covering and stapling (paper, plastic, nylon, jute, wire netting, etc.) and discing (incorporating mulch materials into the soil surface). Furrows made by anchoring may also hold water and sediment. Equipment is available	X		X		X	X	X	X	X	X			I-6 thru I-12

TYPE OF CONTROL MEASURE	CHARACTERISTICS OF MEASURE AND SPECIAL CONSIDERATIONS*	Adjacent Properties	Adjacent Water Bodies	Borrow and Stockpile Areas	Enclosed Drainage (Inlet and Outlet Control)	Large Flat Surface Areas	Medians	Protection From Wind Erosion	Rights of Way	Shoulders	Slopes (Cuts and Fills)	Streams and Waterways	Surface Drainageways	Reference Number (volume II)
	to combine mulch, water and adhesive spray for single application. (Seed sometimes added also.)	X			X							X	X	---
Pipe Outlet Protection	Pipe outlets require a section of protected channel for completing the transition from pipe to channel flow. The needed protection can be provided by energy dissipators, channel protection, or combinations of the two.	X	X	X	X	X	X	X		X	X	X	X	I-3
Plastic Film	Used as a temporary protection for bare soils including channels slopes, borrow or stockpile areas, etc.. May also be used to reduce moisture loss and protect early stages of shrub growth. Plastic film is available in wide rolls or large sheets and is easily placed and removed. *Provides only temporary protection. Original surface usually requires additional treatment when plastic is removed. Must be anchored to prevent wind damage.	X									X	X		I-17
Reinforced Earth Retaining Wall	Modular concrete blocks to whose flat sides are attached long thin metal strips, are stacked on edge to form a wall. The metal strips are laid horizontally and compacted into the backfilled soil on the uphill side of the wall. Friction of the soil on the strips holds the stacked concrete blocks in place, providing a sturdy pervious retaining wall. Particularly useful on slopes steeper than the angle of repose and where horizontal distances are limited.	X									X	X		I-18
Retaining Wall Crib Walls Gravity Walls Cantilever Walls	Used to stabilize steep slopes and prevent earth slides. Can serve as either temporary or permanent structures and are commonly constructed of reinforced concrete, gabions, wood or steel. Counterforts and buttresses are usually added to gravity and crib walls. *Expensive to construct.	X	X		X	X	X	X		X	X	X	X	I-16
Riprap, Rubble	Refers to a layer of loose rock or aggregate placed in an erodible area as surface protection, channel protection or energy dissipator. Effectiveness of coarser grades may be increased by placing a filter beneath. Very effective for high velocities. Can be installed in increments as needed. *Cannot always be placed when needed because of construction traffic and final grading and dressing. Initial cost is high.	X		X		X	X	X	X	X	X	X	X	II-5,6,7
Seeding Aerial (Chopper or Fixed Wing) Broadcasting Drilling Hydroseeding with Mulch and/or Matting	Seeding is inexpensive and easily placed in small quantities with inexperienced personnel. Larger slopes can be seeded with smaller equipment if stage techniques are used. Species selected will depend on total rainfall and distribution and temperature extremes. Generally, annual grasses are used for temporary cover and perennial grasses or legumes for permanent cover. Salt-tolerant species may be required where salt application is anticipated as part of regular road maintenance. *Time of year may be less than desirable. May require supplemental watering. Difficult to schedule high production units for small increments.													

YPE OF CONTROL MEASURE	CHARACTERISTICS OF MEASURE AND SPECIAL CONSIDERATIONS*	Adjacent Properties	Adjacent Water Bodies	Borrow and Stockpile Areas	Enclosed Drainage (Inlet and Outlet Control)	Large Flat Surface Areas	Medians	Protection From Wind Erosion	Rights of Way	Shoulders	Slopes (Cuts and Fills)	Streams and Waterways	Surface Drainageways	Reference Number (volume II)
Seepage Control	Accomplished by covering the surface with a gravel blanket or inserting pipes horizontally into the bank to draw off water. Either method stabilizes the cut surface and prevents sloughing.			X				X	X	X	X			I-21
Sodding	Sod may be hand laid over the entire surface in narrow strips along the contours of a slope. On steep slopes, it may need to be staked to prevent slippage. Another effective use of sod in areas of high rainfall is a 15" wide strip laid along the edges of the pavement of highways to prevent the shoulders from eroding. Sod provides immediate protection and can easily be repaired during construction. Can be used to protect adjacent property from sediment and turbidity. *Requires water during first few weeks. May not always be available. Will not withstand high velocity or severe abrasion from sediment load. May be expensive.	X			X		X	X		X	X	X	X	I-19
Sprigging	Sprigging consists of planting shoots or sprouts as opposed to seeds. It is done to achieve more rapid growth of larger vegetation. Sprigs are either broadcast, punched in or transplanted with special planters.	X		X		X	X	X		X	X	X	X	I-20
Stacked Concrete Bags	May be used for slope protectors at highway overpasses and for channel protectors at pipe outlets. Consist of bags of wet concrete stacked and allowed to dry.				X						X	X	X	IV-5
Stream Bank Protection	Requires large material masses or smaller anchored structures such as large boulders, gabions, brush mats, log jacks, concrete rubble or special concrete and steel structures. Old tires tied together may be used where sediments are likely to accumulate and revegetation will follow.		X									X		IV-5
Stream Channel Change	May be a temporary bypass to permit construction of a bridge or other structure on the main channel, or a permanent change to allow a more desirable alignment of the highway. In either case, the new channel must be protected against erosion with such things as riprap, concrete and large vegetation.											X		III-3
Tubelings	A dry land planting technique that eliminates the need for irrigation during plant establishment and is conducive to mechanization. Plants are grown in 2 1/2" by 24" paper tubes reinforced by plastic mesh sleeves. These tubelings are planted in holes drilled into the ground with a power auger.	X					X	X		X	X			I-22
Vegetative Stabilization Forbs Grasses Legumes Shrubbing Trees	Accomplished by planting imported or native vegetation on cut and fill slopes and other areas needing erosion protection. May serve as both temporary or permanent protection against erosion by intercepting and slowing rainfall and runoff, reducing overland flow volumes through evapotranspiration losses, providing shade and litter to keep soil surface temperatures cool and	X	X	X		X	X	X	X	X	X	X	X	II-1 thru 11

TYPE OF CONTROL MEASURE	CHARACTERISTICS OF MEASURE AND SPECIAL CONSIDERATIONS*	WHERE MEASURE IS USED: Adjacent Properties	Adjacent Water Bodies	Borrow and Stockpile Areas	Enclosed Drainage (Inlet and Outlet Control)	Large Flat Surface Areas	Medians	Protection From Wind Erosion	Rights of Way	Shoulders	Slopes (Cuts and Fills)	Streams and Waterways	Surface Drainageways	Reference Number (Volume II)
	contributing to soil cohesion by root structure. Revegetation should begin as soon as possible after soil is bared to take advantage of available soil moisture.							X	X					I-23
Wattles Brush Straw	Early method used for stabilizing fill slopes. Hand labor required. Leafy brush, straw or both are packed into a "cable" about 12" wide and 10" thick and laid in trenches dug into the slope face along the contours. 1" x 2" x 24" stakes are driven in on 2' centers below the wattles to hold them in place. Live cuttings are planted between the wattles rows and the entire area is seeded.	X			X	X		X	X		X			- - -
Windbreak RUNOFF COLLECTION AND CONVEYANCE	Often in the form of fences - log, lath, plank, board, etc., which reduce wind velocity near the ground. Trees, shrubs and other vegetation are also effective windbreaks.	X	X	X			X			X	X		X	III-2, IV-4
Berms Berm and Ditch Burlap Sand Sausage Diversion Slope	Temporary or permanent berms are made by piling a soil windrow or other obstructions along the shoulders of the roadbed on top of cut to prevent surface runoff from eroding slopes. Require adequate down drains to dispose of water. The burlap sand sausage is made by filling a burlap tube with sand or piling sand on a long piece of burlap and sewing the burlap into a tube. Berms may be constructed before grading is started. May increase water infiltration and soil instability in porous soils. *Concentrates water and may require channel protection on energy dissipation devices.				X						X		X	III-1
Catch Basin	Conveys collected roadway runoff into underground drainage systems. Ensures gutter flow capacity is not exceeded and dissipates energy.			X					X		X		X	III-2
Chutes Asphalt Bare Burlap Concrete Concrete Block Excelsior Fiber Glass Roving Grass Jute Plastic (Nylon) Mat Plastic Sheeting Rock or Riprap Sod Culvert	Used to convey water down slopes and can be either temporary or permanent. *Chutes generally require energy dissipators at the downstream ends. (See also down drains). A conduit used to convey water under roadway, canal or other embankment, usually of corregated metal or reinforced concrete pipe. Should be placed in natural drainages if possible and provided adequate outlet protection.								X		X	X		III-3

TYPE OF CONTROL MEASURE	CHARACTERISTICS OF MEASURE AND SPECIAL CONSIDERATIONS*	WHERE MEASURE IS USED: Adjacent Properties	Adjacent Water Bodies	Borrow and Stockpile Areas	Enclosed Drainage (Inlet and Outlet Control)	Large Flat Surface Areas	Medians	Protection From Wind Erosion	Rights of Way	Shoulders	Slopes (Cuts and Fills)	Streams and Waterways	Surface Drainageways	Reference Number (volume II)
Diversion Dike	Ridge of compacted soil placed above, below or around disturbed area to intercept run-off. Used above newly constructed cut and fill slopes to prevent erosion until permanent slope protection is in place. *Least durable diversion structure. Should only be used as temporary.										X			III-4
Diversion Ditch, Cut Slope	May be temporary or permanent. Constructed at the upper edges of cut slopes to collect water from adjacent properties and divert it around the cut to safe disposal areas or at the perimeter of construction area to transport sediment laden water to trapping device. Materials used to construct these ditches are determined by the slope of the ditch but include sod, gravel, stone, asphalt and concrete. *May require additional right of way or flow easement for construction.	X		X								X		III-4
Drain Dip	Broad, shallow dips are built into unpaved road surface across graded right of way to intercept and divert surface runoff to safe disposal site.. Dips require regular spacing determined by anticipated water velocities and sediment particle size.								X					III-5
Drain, Down Asphalt Burlap Concrete Excelsior Mat Fiber Glass Roving Flexible Pipe Gravel, Rock or Rubble Jute Mesh Plastic Sheeting Rigid Pipe Sod Subsurface Pipe	Used to conduct runoff down a slope. May be open channel or closed conduit, temporary or permanent. Often used to aid disposal of diverted water. (See also Chutes).	X	X	X	X		X		X	X	X	X	X	III-7,12
Dry Well	A gravel filled pit or trench used to store and infiltrate surface runoff.												X	III-6
Inlets Box Drop Down Drain Hooded Pipe Drop	Provide smooth efficient transitions between overland or channel flow and pipe flow. They may serve both temporary and permanent functions. Temporary inlets are constructed of rock and earth, hay bales, wood and other available materials. The more permanent types are usually constructed of concrete. *Burying culvert inlets will decrease abrasion from heavy bed loads.	X	X		X		X		X	X	X	X		III-12 IV-3
Inslope	Technique used where roads are constructed on steep slopes. Runoff is concentrated on the uphill side of the road by means of a ditch. The sides are usually bermed to prevent water from going over the fill.								X					III-5

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Interceptor Dike	Directs overland flow to a desired collection or runoff point. Constructed with any materials that will withstand the anticipated flow velocities. *May be continuing maintenance problem if not paved or protected.	X		X	X	X	X		X		X		X	III-4
Interceptor Ditch or Drain	(See also Slope Drains). Changes course of flow of surface runoff and directs to collection and runoff point. *Construction of ditches and drains is similar to that of most water channels and they must be protected to withstand flow velocities and prevent clogging.	X		X		X	X		X		X		X	III-8
Open Top Culvert Box Top Pole	Provides surface drainage on lightly used, unpaved roads. Culverts consist of box-like frames installed flush with road surface. Box-top should have discharge end wider than intake end to aid self-cleaning. Bottoms should be 3/4" - 1" wider than top. Spacing depends on road grade.								X					III-9
Pipe Drop	A pipe extending from the top to the bottom of a slope. Used to convey surface runoff downslope while preventing erosion.										X			III-12
Roadside Ditch	Side ditch (adjoining road shoulder) to convey excess road surface runoff and prevent erosion of cut and fill slopes.										X			III-10
Spillways Box Inlet Drop Chute Drop Pipe Pipe Drop Straight Drop	Used in conjunction with dams to bypass overflows with minimum erosion.											X	X	- - -
Storm Drains	Collect rainfall or snowmelt runoff and transport to a disposal point. Storm sewers are usually permanent and constructed from durable materials, but may be utilized during the construction phase as well.	X	X		X		X				X	X		III-13
Toe Drain Ditch	Used to collect seepage and runoff from a slope and transport it to a channel. Ditches should be lined with rock riprap or other protective material as needs dictate.										X			III-10
Waterbars	Used to divert water from unpaved road surfaces. Waterbars are cut into solid soil at least 6" deep, skewed across width of road with berms at downgrade side. Spacing and size depend on road grade, soil texture, precipitation and traffic. *Will not withstand traffic.								X					III-4

(Column group heading: WHERE MEASURE IS USED)

TYPE OF CONTROL MEASURE	CHARACTERISTICS OF MEASURE AND SPECIAL CONSIDERATIONS*	Adjacent Properties	Adjacent Water Bodies	Borrow and Stockpile Areas	Enclosed Drainage (Inlet and Outlet Control)	Large Flat Surface Areas	Medians	Protection From Wind Erosion	Rights of Way	Shoulders	Slopes (Cuts and Fills)	Streams and Waterways	Surface Drainageways	Reference Number (volume II)
RUNOFF DISPERSION														
Benches	Reduce slope lengths. Made by constructing wide (say 10' - 20') horizontal, level or slightly reverse sloping steps in intervals (say 50' - 100') down the slope, on or near contours. Increases infiltration by reducing velocities. Also catches sediment, rock or debris. *Requires provision for runoff disposal.			X					X		X			IV-9
Channels Asphalt Bare Burlap Concrete Concrete Block Excelsior Fiber Glass Roving Grass Jute Plastic (Nylon) Mat Plastic Sheeting Rock or Riprap Sod	Used to direct runoff from points of concentration around highway rights of way or other areas to be protected. Channels steeper than approximately 3% need protection against erosion. Allowable slope of bare channels depends on the type of soil. *Channels can be lined with stone or other baffles to act as energy dissipators but size may have to be increased to compensate for slower velocities.	X	X	X	X	X	X		X	X	X	X	X	IV-5,6
Check Dams Concrete Graded Stone Log Log and Hay Rock and Fence Sheet Piling Staked Bales Straw Bales and Fence	May be temporary or permanent. Prevents channel erosion and allows settling of suspended soils. Constructed by placing selected material across the channel normal to the flow. Dam height is dictated by flow volume and channel slope. *Requires close spacing on steep grades and regular cleaning. Should be inspected for damage following storms.	X	X	X	X		X			X		X	X	IV-1
Drain, Slope Asphalt Concrete Flexible Pipe Metal Pipe Plastic Pipe	(See also Interceptor Drains). Placed horizontally at vertical intervals on long slopes to reduce the effective slope length. These drains can be of any open channel cross section and must be lined. Usually function both as temporary and permanent structures. Can be constructed or extended as grading progresses. *Requires supporting effort to collect water. Permanent construction is not always compatible with other project work. Usually requires some type of energy dissipation.	X	X	X	X	X	X		X	X	X	X	X	III-7,12
Drop Box Culvert	(See also Inlets). Consists of a culvert inlet-box with vertical sides. Acts as an energy dissipator and reduces velocity in culvert. This type of structure is usually permanent except in temporary sediment basins, and is constructed of steel, wood or concrete.	X	X	X	X						X	X	X	V-3
Energy Dissipators Boulders Concrete Concrete Blocks Gabions Metal Apron Riprap Rock Sausages Water Pool	Convert high velocity flows from paved channels and/or conduits to lower velocity flows. Materials used are frequently gabions, concrete aprons or large boulders. *Collects debris and therefore requires regular cleaning.				X							X	X	- - -

WHERE MEASURE IS USED

TYPE OF CONTROL MEASURE	CHARACTERISTICS OF MEASURE AND SPECIAL CONSIDERATIONS*	Adjacent Properties	Adjacent Water Bodies	Borrow and Stockpile Areas	Enclosed Drainage (Inlet and Outlet Control)	Large Flat Surface Areas	Medians	Protection From Wind Erosion	Rights of Way	Shoulders	Slopes (Cuts and Fills)	Streams and Waterways	Surface Drainageways	Reference Number (Volume II)
Erosion Check Fiberglass Roving Jute Plastic	Porous, mat-like material installed perpendicular to flow direction in a ditch or channel to prevent channel erosion and provide grade control.	X	X										X	IV-4
Gabions	(See description under SURFACE STABILIZATION).													
Level Spreader	A level spreader is a type of berm that serves as a permanent method of converting channel or pipe flow to sheet flow, thereby reducing velocity and increasing infiltration. Compacted soil, soil cement or asphalt mixtures are used for construction. *Level spreader surfaces may need sod or other material to protect them from erosion. Adequate spreader length may not be available.	X		X					X		X		X	IV-7
Minibenches	Used on steep slopes to increase infiltration and reduce runoff velocities. Improve seedbed by retaining moisture. Horizontal steps with horizontal and vertical dimensions greater than 1' are graded into slope.										X			IV-9
Outslope	Outsloping is a technique used where roads are constructed on steep slopes. Runoff is dispersed over the downhill edge of the roadway using drain dips to convey runoff across the roadway. *May be unsafe for slippery or heavily traveled roads.								X					III-5
Riprap	(See description under SURFACE STABILIZATION).													
Rolling Grade	Rolling grades at intervals determined by runoff volumes, soil and topography, aids dispersal of surface water and prevents puddling on road surface.								X					- - -
Roughened Surface	An unsmoothed fill surface that has been ripped, ploughed or disked and holds water for seed and mulch, thereby decreasing runoff volume.								X		X			IV-8,9
Selective Grading and Shaping	Involves a nonstandard grading and shaping of slopes in critical areas where erosion potential is high. Water can be directed to minimize off-site damage. Flatter slopes enable mulch to be cut into soil.										X			- - -
Serrated Cuts	Increase infiltration and reduce water velocities down cut slopes. Also provide a better seedbed for establishing vegetation and help retain moisture. Horizontal steps with horizontal and vertical dimensions less than 1' are constructed with a grader as the cut is made. *May cause minor sloughing if water infiltrates.										X			IV-8
<u>SEDIMENT COLLECTION</u>														
Barrier, Temporary Brush Fence Hay or Straw Bales	Should be constructed before excavation to impede surface runoff and stop movement of sediment, mulch or other surface protectors. Slash and haybales used on medium slopes or at the toes of steep slopes. Fence also used on slopes. Made by piling or staking on or near a contour along the surface to be protected. Also serves as a filter on berm. Can be covered and seeded rather than removed. Eliminates need for burning or disposal off right of way. *May be considered unsightly in urban areas.	X			X		X	X			X	X	X	V-1

TYPE OF CONTROL MEASURE	CHARACTERISTICS OF MEASURE AND SPECIAL CONSIDERATIONS*	Adjacent Properties	Adjacent Water Bodies	Borrow and Stockpile Areas	Enclosed Drainage (Inlet and Outlet Control)	Large Flat Surface Areas	Medians	Protection From Wind Erosion	Rights of Way	Shoulders	Slopes (Cuts and Fills)	Streams and Waterways	Surface Drainageways	Reference Number (volume II)
Cofferdam Concrete Earth Steel Supported Plastic Sheet Wood Other	Diverts water from structures or stream bank segments during construction to prevent sediment from entering adjacent streams. *Usually expensive to construct.			X								X		V-12
Culvert Riser	Permits inlet areas to serve as temporary or permanent sediment traps. May consist of corrugated metal pipe attached to inlet of culvert and extending upward.	X	X								X	X	X	V-11
Filter Berm Brush Baled Hay or Straw Nylon Cloth Rock or Gravel Sediment Basin Outlet Sediment Trap	Often used around drain inlets, along toes of slopes. on small slopes and sediment basin dams. Filters can be simply constructed from any porous material that can be stabilized in rows, banks, or mounds. *Must be cleaned regularly. Breakage of strings on straw/hay bales due to vandalism or deterioration (3 - 6 months) can block downstream drainage.	X	X	X	X	X	X		X	X	X	X	X	V-4,5
Floating Sediment Barrier of Diaper	Retains suspended sediment within the disturbed area of a lake, pond or stream. The diaper is a plastic or other impermeable barrier suspended from floats tied together with a rope and anchored at each end to the shore. Both barriers extend from the water surface to within a few inches of the lake bed.		X									X		V-12
Sediment Basin	Controls or stops movement of eroded sediment. Basins are quite large as compared to traps and receive runoff from large areas. Each consists of a dam, an outlet structure and water storage space. Most sediment in flowing water will settle out in a basin if the detention time is adequate. *Must be cleaned regularly. May require additional right of way or flow easement for construction. Access for cleanout is not always convenient.	X	X						X			X		V-7
Sediment Traps Board Dam at Inlet Catch Basin Culvert Excavated Inlet	Sediment traps are small sediment basins. They are inexpensive, simple to construct and should be used extensively during construction. They are made by digging holes in medians and other drainageways by building small dams of wood, stone, bales, etc. across channels, culvert inlets, and other low areas. Can be supported by filters. Generally used for drainage area less than 5 - 10 acres. *Cleaning is required when 1/2 - 2/3 capacity is filled.	X	X	X	X	X	X		X	X	X	X	X	V-8
Silt Fence	Consists of filter cloth backed by a wire net fence mounted on posts. Very effective for retaining sediment on right-of-way. Used at culvert outlets, toe of fills and downhill side of cut slopes. *Sediment should be removed when 1/2 height of fence.	X	X			X			X			X	X	V-5
Vegetative Buffer Strip	A strip of dense vegetation is used to prevent sedimentation or erosion at critical areas. It is often used along boundaries to prevent deposition of sediment onto adjacent property or into waterbodies. Vegetative species chosen for manmade buffer strips should be deep rooted and able to adjust to low oxygen levels (willows, alder).	X	X	X		X	X	X		X	X	X	X	V-10

SECTION 4

PROGRAM COORDINATION AND EVALUATION OF BMP'S

PROGRAM COORDINATION AND EVALUATION OF BMPS.

IMPLEMENTATION ALTERNATIVES

Implementation of the guidelines and methods presented in volumes I and II of the Road Construction BMPs will be initiated through cooperative agreements between IDHW and management agencies having jurisdiction over road activities. Copies of these agreements can be found in Appendix V.

It is anticipated that the BMPs for Road Activities may be incorporated into the Idaho Water Quality Standards and Wastewater Treatment Requirements during future revisions to these standards. Both volumes would then be referenced as "approved" Best Management Practices under Section 1-2300.05.

If such revision were proposed, the public would be afforded comment and hearings as provided by the Administrative Procedures Act (Chapter 52, Idaho Code).

STATE AND FEDERAL MANAGEMENT AGENCIES

The following briefly describes agencies having jurisdiction over road construction activities and their existing involvement. Please note the IDL and IDWR regulations which are applicable to road construction special activities or in special areas.

Idaho Department of Health and Welfare - Division of Environment (IDHW-DOE)

The Director of the Idaho Department of Health and Welfare is responsible for administration of the "Environmental Protection and Health Act of 1972" (Title 39, Idaho Code), under this Act, IDHW supervises and administers a system to safeguard water quality and recommends water quality protective rules, regulations, and standards to the IDHW Board. The IDHW-DOE administers the State Water Quality Standards as adopted by the State Board of Health (pursuant to Title 39, Chapter 1, Chapter 52, and Idaho Session Laws 1973). These regulations are updated every three years and designed to protect water quality for designated and beneficial uses through required application of best management practices where non-point sources of pollution exist (Section 1-2300). Use designations for specific stream reaches (Section 1-2110 through 1-2160.02) include agricultural water supplies, domestic water supplies, cold water biota, warm water biota, salmonid spawning, primary contact recreation and secondary contact recreation. Other sections of the standards which may apply to road and hazardous material storage. IDHW-DOE is currently developing criteria to evaluate water quality impacts of sediment pollution. The proposed criteria will be reviewed within the next year by the Board of Health and Welfare for adoption as formal Department policy or incorporation into the existing Water Quality Standards.

In the case that State standards may become less stringent than Federal water quality standards, the U.S. Environmental Protection Agency is authorized to promulgate Federal standards.

Idaho Department of Lands (IDL)

The Idaho Department of Lands has jurisdiction over private and state endowment lands as set forth in "Statutes and Regulations Pertaining in the

Idaho Department of Public Lands", August 1976. IDL administers the Idaho Forest Practices Act of 1974 (Title 38, Chapter 13, Idaho Code) which includes minimum standards for road construction and maintenance during forestry operations on all non-federal lands (Section 814). The IFPA is based on a policy to encourage forest practices that maintain and enhance resource benefits. (Appendix III).

Idaho Department of Water Resources (IDWR)

The Idaho Department of Water Resources has authority to regulate in-stream construction under the Stream Channel Protection Act of 1971 (Title 42, Chapter 38, Idaho Code). Rules, regulations, and minimum standards developed under this Act prescribe conditions for permit approval on all in-stream construction within the State. (Appendix II). Dry wells (over 18 feet in-depth) installed in conjunction with road drainage are subject to IDWR's Regulations for Waste Disposal and Injection Wells (1980) under Title 42, Chapter 39 Idaho Code. Copies of these rules are available from IDWR.

IDWR coordinates State comment for two Federal permit programs, administered by the Department of the Army - Corps of Engineers (COE). Section 10 of the Rivers and Harbors Act of 1899 (30 Stat. 1151; 33 USC: 403) and Section 404 of the Clean River Act respectively prohibit unauthorized obstructions or alterations of any navigable U.S. waters and discharge of dredged or fill material into all waters and adjacent wetlands.

IDWR policy declares that public safety, health and welfare require stream channels of the State and their environments to be protected against alteration for the protection of fish and wildlife habitat, aquatic life, recreation, aesthetic beauty and water quality.

Idaho Transportation Department (ITD)

The Idaho Transportation Department is responsible for proper planning, engineering, construction, maintenance, operation, and protection of the State Highway System. Included are all projects constructed under the Federal Aid Highway Acts and those covered under Sections 131, 136, 151, 155, and 319(b) of Title 23 U.S.C.. Idaho Code Sections 40 - 106, 109, 111, 112, and 136 establish a permanent policy of highway improvement within the State with implementation authority assigned to State, County, and Municipal Road Districts. Local highway districts assume responsibility for all roads and streets where county populations exceed 75,000 persons (Section 40 - 3001). Cities are delegated authority for city street maintenance under Section 40 - 136 Idaho Code.

ITD has memorandums of understanding with the USDA - Forest Service and Idaho Department of Fish and Game providing for interagency review of transportation plans in predetermined areas of National Forest land.

Federal Highway Administration (FHWA)

The Federal Highway Administration provides guidance to the state and local agencies on projects funded through the Federal-Aid Highway Program under the authority of Title 23 of U.S. Code. The respective highway agency has the responsibility for planning, developing, constructing, and maintaining the individual projects. The Federal Highway Administration is responsible for review and approval of each major activity.

U.S. Department of Agriculture - Forest Service (USFS)

The USDA - Forest Service has authority to manage National Forest lands as delineated in the National Forest Management Act. Standard operating procedures for road construction activities are described in the Forest Service Transportation Systems Manual series 7700 (7710 - planning, 7720 - development, 7730 - operations). Forest Service policy is guided by the Federal Land Policy and Management Act of 1976 which requires protection of multiple use and sustained yield for public benefit.

U.S. Department of the Interior - Bureau of Land Management (BLM)

The Bureau of Land Management has jurisdiction over unappropriated public lands. BLM's Division of Engineering Chief is responsible for developing and maintaining standards and procedures for transportation systems planning on public lands (Title 23 U.S.C.). Standards and procedures are outlined in the BLM 9110 Transportation Systems Manual Series. Although transportation route selections are based on most economic access (9113.02), overall land management activities must comply with sustained yield and multiple use requirements of the Federal Land Policy and Management Act of 1976 as amended.

U.S. Department of Labor - Mine Safety and Health Administration (MSHA)

The Mine Safety and Health Administration is responsible for assuring that Federal Safety requirements are met on roads used on mining operations. Included in the Regulations and Standards Applicable to Metal and Non-Metal Mining and Milling Operations are provisions for berm construction as necessary to ensure road safety (Title 30 CFR - Chapter 1, Section 55, 9 - 22 and 55, 9 - 54). In addition, travelway design, installation and maintenance is required to be in a safe manner consistent with speed and type of haulage (Section 55, 9 - 16).

RELATED LEGISLATION

The Intergovernmental Cooperation Act of 1968 requires that urban land transactions entered into on behalf of Federal agencies, must, to the greatest extent practicable be consistent with zoning and land use practices and avoid conflict with planning and development objectives of the local planning agencies concerned. The Act also requires a State and local government review of Federal programs having significant impact on area and community development.

Executive Order 11990 - Protection of Wetlands (1977) directs Federal agencies to take action to minimize destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial value of wetlands in carrying out programs affecting land use.

Executive Order 11998 - Protection of Floodplains (1977) directs Federal agencies to reduce the risk of flood loss to minimize the impact of floods on human safety, health and welfare, and to restore and preserve the natural and beneficial values served by floodplains in carrying out programs affecting land use.

The Federal Land Policy and Management Act (1976) directs the Secretary of the Interior to manage public lands under the principles of multiple use and sustained yield in a manner that will protect scenic, historical, ecological, environmental, air and atmospheric, and water resources, and archeologic value.

The Watershed Protection and Flood Prevention Act (1954) mandates the Federal government to cooperate with the States and political subdivisions, soil and water conservation districts, flood prevention or control districts and other local public agencies for the purpose of preventing erosion or floodwater and sediment damage in watersheds of rivers and streams.

EVALUATION OF BMPs

As of this writing, IDHW-DOE has no monitoring plan for evaluating the effectiveness of the Road Activities BMPs in protecting water quality. Agencies involved in road work are encouraged to devise their own BMP evaluation procedures and make recommendations for change as support data becomes available.

Although IDHW-DOE has no specific plan for direct evaluation of BMP effectiveness in protecting water quality, a sediment "standard" has been developed which may prove to be a useful evaluation tool. This standard consists of sediment rating curves. The rating curve approach addresses the relationships between natural variability, beneficial uses and land use practices.

A sediment rating curve is a mathematical expression of the relationship between suspended sediment concentrations and stream discharge. Curves are developed for specific stream reaches using sediment and discharge data collected over a broad range of flow conditions. An allowable error band can be established around the curve defining the limits beyond which observed sediment concentrations would be attributed to factors other than chance. When developed for defined baseline conditions, rating curves can be used as a management tool to detect changes in stream sediment concentrations due to land use practices. Values exceeding the limits defined by the curve could be attributable to some land disturbing activity occurring higher in the watershed since change due to natural variability is inherent.

This sediment "standard" based on the rating curve approach has yet to be approved by the IDHW Board. This standard will be proposed as an addition to the Idaho State Water Quality Standards and Wastewater Treatment Requirements during future revisions.

GLOSSARY

GLOSSARY

ABUTEMENT - An anchorage for the cables of a suspension bridge or aerial railway; the part of a structure that directly receives thrust or pressure (as of an arch).

ANGLE OF REPOSE - Angle between the horizontal and the maximum slope that a soil or other material assumes through natural processes.

APRON - A floor or lining to protect a surface from erosion, for example, the pavement below chutes, spillways, culverts, or at the toes of dams.

ASPECT - The direction that a slope faces.

BENCH - A relatively level step excavated into earth material on which fill is to be placed.

BERM - A raised and elongated area of earth for erosion control intended to direct the flow of water.

BORROW - Earth material acquired from an off-site location for use in grading on a site.

BORROW PIT - The excavation resulting from the extraction of borrow soil materials.

BROADCAST SEEDING - Scattering seed on the surface of the soil. Contrast with drill seeding which places the seed in rows in the soil.

CHANNEL - A natural stream that conveys water, a ditch or channel excavated for the flow of water.

CHANNEL STABILIZATION - Erosion prevention and stabilization of velocity distribution in channel using drops, revetments, vegetation, and other measures.

CHECK DAM - Small dam constructed in a gully or other small watercourse to stabilize the grade and control head cutting.

CHUTE - A high-velocity, open channel for conveying water to a lower level without erosion.

CLAY - (1) Mineral soil grains less than 0.002 in millimeter in equivalent diameter. (2) A soil texture class. (3) (Engineering) A fine-grained soil that has a high plasticity index in relation to the liquid limits.

CLEARING - The removal of vegetation, structures, or other objects.

COMPACTION - The densification of a fill by mechanical means.

CONTOUR - The shape of a land surface as expressed by contour lines.

CONTOUR GRADING PLAN - A drawing showing an arrangement of contours, intended to integrate construction and topography, improve appearance, retard erosion, and improve drainage.

CREEP - Slow mass movement of soil and soil material down relatively steep slopes primarily under the influence of gravity, but facilitated by saturation with water, strong winds, and by alternate freezing and thawing.

CRITICAL AREA - A severely erodible area.

CUT - An excavation. The difference between a point on the original ground and a designated point of lower elevation on the final grade. Also, the material removed in excavation.

DAM - A barrier to confine or raise water for storage or diversion, to create a hydraulic head, to prevent gully erosion, or for retention of soil, rock, or other debris.

DEBRIS - A term applied to the loose material arising from the disintegration of rocks and vegetative material; transportable by streams, ice, or floods.

DEBRIS DAM - A barrier built across a stream channel principally to retain rock, sand, gravel, silt, or other material, such as trash or leaves.

DIKE - A berm of earth or other material constructed to confine or control surface water in an established drainage system.

DIVERSION - A diversion is a temporary or permanent structure consisting of a channel or ditch and a ridge constructed across a sloping land surface on the contour or with predetermined grades to intercept and divert surface runoff before it gains sufficient volume and velocity to cause erosion.

DRAINAGE - The removal of excess surface water or groundwater from land by means of surface or subsurface drains.

DRAINAGE PATTERN - The configuration or arrangement of streams within a drainage basin or other area.

DRILL SEEDING - Planting seed with a drill in relatively narrow rows, generally less than a foot apart. Contrast with broadcast seeding.

DROP-INLET SPILLWAY - Overfall structure in which the water drops through a vertical riser connected to a discharge conduit.

EASEMENT (CONSTRUCTION, DRAINAGE, PLANTING SLOPE) - A right to use or control the property of another for designated purposes.

ECOSYSTEM - A community of organisms and the surroundings in which they live.

ENERGY DISSIPATOR - A device used to reduce the excess energy of flowing water.

ERODIBLE - Susceptible to erosion.

EROSION - The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep.

EROSION AND SEDIMENT CONTROL PLAN - A plan which fully indicates necessary land treatment and structural measures, including a schedule of the timing for their installation, which will effectively minimize soil erosion and sediment yield.

EXCAVATION - Any activity by which earth, sand, gravel, rock, or any other similar material is dug into, cut, quarried, uncovered, removed, displaced, relocated or bulldozed and shall include the conditions resulting therefrom.

EXISTING GRADE - The grade prior to grading.

FERTILIZER - Any organic or inorganic material of natural or synthetic origin which is added to a soil to supply certain elements essential to the growth of plants.

FILL - A deposit of earth material placed by artificial means; any act by which earth, sand, gravel, rock, or any other material is placed, pushed, dumped, pulled, transported, or moved to a new location above the natural surface of the ground or on top of the stripped surface and shall include the conditions resulting therefrom. The difference in elevation between a point on the original ground and a designated point of higher elevation on the final grade.

FILTER BLANKET - A layer of sand and/or gravel designed to prevent the movement of fine-grained soils.

FILTER STRIP - Strip of vegetation that retards flow of runoff of water, causing deposition of transported material, thereby reducing sediment flow.

FINISH GRADE - The final grade of the site which conforms to the approved plan.

FLOCCULATION - Aggregation of suspended particles; addition of flocculating agent.

FLOOD PLAIN - The relatively flat area adjoining the channel of a natural stream which has been or may be hereafter covered by flood water.

GRADE - (a) The slope of a road, channel, or natural ground. (b) The finished surface of a canal bed, roadbed, top of embankment, or bottom of evcavation; any surface prepared for the support of construction, like paving or laying a conduit. (c) To finish the surface of a canal bed, roadbed, top of embankment, or bottom of excavation.

GRADIENT - Change of elevation, velocity, pressure, or other characteristics per unit length of slope.

GRADING - Any stripping, cutting, filling, stockpiling, or any combination thereof and shall include the land in its cut or fill condition.

GROUNDWATER - Phreatic water or subsurface water in the zone of saturation.

GRUBBING - The process of removing roots, stumps, and low-growing vegetation.

GULLY - A channel or miniature valley cut by concentrated runoff but through which water commonly flows only during and immediately after heavy rains or during the melting of snow. The distinction between gully and rill is one of depth. A gully is sufficiently deep that it would not be obliterated by normal tillage operations, whereas a rill is of lesser depth and would be smoothed by ordinary farm tillage.

HABITAT - The place where a given organism lives.

HAUL ROAD - A temporary road, generally unimproved, used to transport material to and from highway construction, borrow pits, and waste areas.

HIGH-WATER MARK - Water level characteristic of highest seasonal flow depth.

HYDRAULIC JUMP - Sudden rise in water level from a flow stage below critical depth to flow stage above critical depth, during which the velocity passes from supercritical to subcritical.

INFILTRATION - The flow of a liquid into a substance through pores or other openings, connoting flow into a soil in contradistinction to "percolation," which connotes flow through a porous substance.

INLET - The upstream end of any structure through which water may flow.

INTERCEPTION CHANNEL (diversion channel) - A channel excavated at the top of earth cuts, at the foot of slopes, or at other critical places to intercept surface flow; a catch drain.

KEY - A designed compacted fill placed in a trench excavated in earth material beneath the toe of a proposed fill slope.

LAND DISTURBANCE - Any activity involving the clearing, grading, filling, and any other activity which causes land to be exposed to the danger of erosion.

LANDSLIDE - The failure of a slope in which the movement of the soil mass takes place along interior surfaces of sliding.

LEGUME - A member of the legume or pulse family, Leguminosae. One of the most important and widely distributed plant families. The fruit is a "legume" or pod that opens along two sutures when ripe. Flowers are usually papilionaceous (butterflylike). Leaves are alternate, have stipules, and are usually compound. Includes many valuable food and forage species, such as the peas, beans, peanuts, clovers, alfalfas, sweet clovers, lespedezas, vetches, and kudzu. Practically all legumes are nitrogen-fixing plants.

LEVEL SPREADERS - A shallow excavation at the outlet end of a division with a level section for the purpose of diffusing the diversion outflow.

LINING - A protective covering over all or part of the perimeter of a reservoir or a conduit to prevent seepage losses, withstand pressure, resist erosion, and reduce friction or otherwise improve conditions of flow.

MEDIAN - The portion of a divided highway separating the roads for traffic in opposite directions.

MULCH - A natural or artificial layer of material placed on exposed earth to provide more desirable moisture and temperature relationships for plant growth. It is also used to control the occurrence of unwanted vegetation.

NATIVE SPECIES - A species that is a part of an area's original fauna or flora.

OUTFALL - The point where water flows from a conduit, stream, or drain.

OUTLET - Point of water disposal from a stream, river, lake, tidewater, or artificial drain.

PRODUCTIVITY, SOIL - The capacity of a soil, in its normal environment, for producing a specified plant or sequence of plants under a specified system of management. The "specified" limitations are necessary since no soil can produce all crops with equal success nor can a single system of management produce the same effect on all soils. Productivity emphasizes the capacity of soil to produce crops and should be expressed in terms of yields.

RAINFALL INTENSITY - The rate at which rain is falling at any given instant, usually expressed in inches per hour.

REVETMENT - A facing of stone or other material, either permanent or temporary, placed along the edge of a stream to stabilize the bank and protect it from the erosive action of the stream.

RILL EROSION - An erosion process in which numerous small channels only several inches deep are formed; occurs mainly on recently cultivated soils.

RIPRAP - Broken rock, cobbles, or boulders placed on earth surfaces, such as the face of a dam or the bank of a stream, for protection against the action of water (waves); also applied to brush or pole mattresses, or brush and stone, or other similar materials used for soil erosion control.

ROUNDING, SLOPE - The modeling or contouring of roadside slopes to provide a curvilinear transition between several planes; e.g., tops, bottoms, and ends of cuts and fills.

RUNOFF - The surface water flow or rate of flow over a given watershed after a fall of rain or snow melt.

SAND - (1) A soil particle between 0.05 and 2.0 millimeters in diameter. (2) Any one of five soil separates: very coarse sand, coarse sand, medium sand, fine sand, and very fine sand. (3) A soil textural class.

SCOUR - To abrade and wear away. Used to describe the wearing away of terrace or diversion channels or streambeds.

SEDIMENT - Solid material, both mineral and organic, that is in suspension, is being transported, or have been moved from its side of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

SEDIMENT DETENTION BASIN - A sediment detention basin is a reservoir which retains flows sufficiently to cause deposition of transported sediment.

SEDIMENT LOAD - The quantity of sediment, measured in dry weight, or by volume, transported through a stream cross section in a given time. Sediment load consists of both suspended load and bedload.

SEDIMENTATION - The process by which mineral or organic matter is removed from its site of origin, transported, and deposited by water, wind, or gravity.

SEEDBED - The soil prepared by natural or artificial means to promote the

germination of seeds and the growth of seedlings.

SEEPAGE - (1) Water escaping through or emerging from the ground along an extensive line or surface as contrasted with a spring where the water emerges from a localized spot. (2) The process by which water percolates through the soil.

SETTLING BASIN - An enlargement in the channel of a stream or a dammed area to permit the settling of debris carried in suspension.

SHEET EROSION - The removal of a fairly uniform layer of soil from the surface by runoff water.

SHEET FLOW - Water, usually storm runoff, flowing in a thin layer over the ground surface. Synonym: overland flow.

SIDE SLOPES - The slope of the sides of a canal, dam, or embankment. It is customary to name the horizontal distance first, as 1.5 or 1, or frequently 1 - 1/2: 1, meaning a horizontal distance of 1.5 feet to 1 foot vertical.

SILT - (1) A soil separate consisting of particles between 0.05 and 0.002 millimeter in equivalent diameter. (2) A soil textural class.

SITE - Any lot or parcel of land or contiguous combination thereof, under the same ownership, where grading is performed or permitted.

SLASH - The branches, bark, tops, cull logs, and broken or uprooted trees on the ground after logging.

SLIP - The downslope movement of a soil mass under wet or saturated conditions; a microlandslide that produces a microrelief in soils.

SLOPE - The degree of deviation of a surface from the horizontal, usually expressed in a ratio, percent, or degrees. The face of an embankment or cut section.

SLOPE CHARACTERISTICS - Slopes may be characterized as concave (decrease in steepness in lower portion), uniform, or convex (increase in steepness at base). Erosion is strongly affected by shape, ranked in order of increasing erodibility from concave to uniform to convex.

SLOPE DRAINS - Permanent or temporary devices that are used to carry water down cut or embankment slopes. May be pipe, half sections, paved or special plastic lining.

SOD - A closely-knit ground cover growth primarily of grasses.

SOIL - The unconsolidated mineral and organic material on the immediate surface of the earth.

SOIL STRUCTURE - The combination or arrangement of primary soil particles into secondary particles, units, or peds.

SOIL SURVEY - A general term for the systematic examination of soils in the field and in laboratories; their description and classification; the mapping

of kinds of soil; the interpretation of soils according to their adaptability for various crops, grasses, and trees; their behavior under use or treatment for plant production or for other purposes.

SOIL TEXTURE - Soil textural class names of soils are based upon the relative percentages of sand, silt, and clay.

SPRIGGING - The planting of a portion of the stem and/or root of grass.

STRIPPING - Any activity which significantly disturbs vegetated or otherwise stabilized soil surface including clearing and grubbing operations.

STILLING BASIN - An open structure or excavation at the foot of an overfall, chute, drop, or spillway to reduce the energy of the descending stream.

TOE (ENGINEERING) - The lower edge or edges of a slope.

TOLERANT - Capable of growth and survival under competitive growing conditions.

TOPOGRAPHY (LAY-OF-THE-LAND) - The configuration of the earth's surface, including the shape and position of its natural and man-made features.

TOPSOIL - The upper layer of soil containing organic matter and usually suited for plant survival and growth. On a construction site the topsoil is commonly saved for topsoiling.

TRANSPIRATION - The process by which water vapor is released to the atmosphere by the foliage or other parts of a living plant.

TRAP EFFICIENCY - A measurement of the effectiveness of a basin to trap sediment.

VEGETATION - Plant life collectively.

WASTE (CONSTRUCTION) - Excess earth, rock, vegetation, or other materials resulting from highway construction.

WATER TABLE - The upper suface of groundwater or that level below which the soil is saturated with water; locus of points in soil water at which the hydraulic pressure is equal to atmospheric pressure.

WATERCOURSE - A permanent stream; intermittent stream; river; brook; creek; channel or ditch for water, whether natural or man-made.

WATERSHED - All the land and water within the confines of a drainage divide.

WATERWAY - A natural course or constructed channel for flow of water.

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REFERENCES AND ILLUSTRATIONS

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APPENDICES

APPENDIX I

Idaho Soil Conservation District Offices

Location	Phone
Ada SCD P.O. Box 421 Meridian, Idaho 83642	888-1890
Adams SCD P.O. Box P New Meadows, Idaho 83654	347-2512
Balanced Rock SCD 1701 Main St. Buhl, Idaho 82216	342-4148
Bear Lake SCD 110 N. 5th St. Montpelier, Idaho 83254	847-0585
Benewah SCD P.O. Box 406 St. Maries, Idaho 83861	245-2314
Blaine SCD P.O. Box 1300 Hailey, Idaho 83333	788-2254
Bonner SCD Rt. 2, Box 178 Sandpoint, Idaho 83864	263-5310
Boundary SCD P.O. Box 23 Bonners Ferry, Idaho 83805	267-3340
Bruneau River SCD P.O. Box 167 Grand View, Idaho 83624	834-2299
Butte SCD P.O. Box "S" Arco, Idaho 83213	527-8557
Camas SCD P.O. Box 156 Fairfield, Idaho 83327	764-2284
Canyon SCD Arthur St. Caldwell, Idaho 83605	454-8684

Location	Phone
Caribou SCD 159 East 2nd South #2 Soda Springs, Idaho 83276	547-3651
Central Bingham SCD P.O. Box 1026 Blackfoot, Idaho 83221	785-6505
Clark SCD P.O. Box 126 Rexburg, Idaho 83440	356-6931
Clearwater SCD Rt. 2, Box 7C Orofino, Idaho 83544	476-5313
Custer SCD P.O. Box 305 Challis, Idaho 83226	879-4428
East Cassia SCD 2207 Overland Burley, Idaho 83318	678-1225
East Side SCD 1610 Bennett Avenue Idaho Falls, Idaho 83401	522-5137
Elmore SCD 282 S. 3rd West Mountain Home, Idaho 83647	587-3616
Franklin SCD P.O. Box 426 Preston, Idaho 83263	852-0562
Gem SCD 1646 N. Washington Emmett, Idaho 83617	365-4212
Gooding SCD 122 5th Avenue West Gooding, Idaho 83330	934-8481
Idaho SCD 711 W. North Street :angeville, Idaho 83530	983-2330
Jefferson SCD 182 East Fremont Rigby, Idaho 83442	745-6662

Location	Phone
Kootenai-Shoshone SCD 205 N. 4th Street, Rm 215 Coeur d'Alene, Idaho 83814	664-3417
Latah SCD P.O. Box 9244 Moscow, Idaho 83843	882-0507
Lemhi SCD P.O. Box 550 Salmon, Idaho 83467	756-4261
Lewis SCD P.O. Box 67 Craigmont, Idaho 83523	924-5561
Madison SCD P.O. Box 126 Rexburg, Idaho 83440	356-6931
Minidoka SCD Route 1, Box 15 Rupert, Idaho 83350	436-4202
Mud Lake Terreton, Idaho 83450	663-4463
Nez Perce SCD 3510 12th Street Lewiston, Idaho 83501	746-9886
North Bingham SCD 221 S. Emerson P.O. Box 541 Shelley, Idaho 83274	No Phone
North Side SCD 104 S. Lincoln Avenue Jerome, Idaho 83338	324-2501
Oneida SCD 30 North 100 West Malad, Idaho 83252	766-4748
Owyhee SCD P.O. Box 486 Marsin, Idaho 83639	896-4544

Location	Phone
Payette SCD P.O. Drawer B Payette, Idaho 83661	642-4049
Portneuf SCD Suite 112 250 S. 4th Street Pocatello, Idaho 83201	236-6909
Power SCD P.O. Box 325 American Falls, Idaho 83211	226-2177
Snake River SCD 634 Addison Ave. West Twin Falls, Idaho 83301	733-5380
South Bingham SCD P.O. Box 243 Aberdeen, Idaho 83210	397-4917
Squaw Creek SCD 1646 N. Washington Emmett, Idaho 83617	365-4212
Teton SCD P.O. Box 87 Driggs, Idaho 83422	354-2955
Twin Falls SCD 634 Addison Ave. West Twin Falls, Idaho 83301	733-5380
Valley SCD P.O. Box 636 Donnelly, Idaho 83615	325-8567
Weiser River SCD 315 West 2nd Street Weiser, Idaho 83672	549-0622
West Cassia SCD 2207 Overland Burley, Idaho 83318	678-1225
West Side SCD 1610 Bennett Ave. Idaho Falls, Idaho 83401	522-5137

Location	Phone
Wood River SCD P.O. Box 398 Shoshone, Idaho 83352	886-2258
Yellowston SCD P.O. Box 53 St. Anthony, Idaho 83445	624-3341

Soil Conservation Service

State and Area Offices

STATE OFFICE

Room 345
304 N. Eighth Street
Boise, ID 83702

State Conservationist's Office	334-1601
Engineering Division	334-1444
Resource Division	334-1610
Soils Division	334-1348
Snow Survey	334-1613
Project Planning and River Basin Staff	334-1813
Moscow Area Office Room 225 220 East Fifth Street P.O. Box 8307 Moscow, ID 83843	882-4631
Boise Area Office Room 308A 2404 Bank Drive Boise, ID 83705	384-1034
Pocatello Area Office 350 E. Lander Pocatello, ID 83201	236-6843

APPENDIX II

RESEARCH AGENCIES

The following list is intended to provide agency contacts for obtaining erosive control research information as it becomes available. Several national organizations which publish transportation and erosion control information on a regular basis are also listed and briefly described.

Agencies

Environmental Protection Agency - Region X
1200 Sixth Avenue
Seattle, WA 98101

Federal Highway Administration
Office of Research
Environmental Design and Control Division
400 Seventh Street S.W.
Washington, DC 20590
1-202-426-0539

Highway Research Board, Manager
2101 Constitution Avenue NW
Washington, DC 20418

Highway Research Information Service
John Henry Building
Room 515
2100 Pennsylvania Avenue NW
Washington, DC 20418

Soil Conservation Service
Plan Materials Center
Experiement Station
P.O. Box AA
Aberdeen, ID 83210
397-4181

Soil Conservation Service
Plant Materials Center
Room 257, Johnson Hall
Washington State University
Pullman, WA 99163
509-332-2024

Soil Conservation Service
Department of Plant and Soil Service
College of Agriculture
University of Idaho
Moscow, ID 83843
885-7012

USDA - Science Education Administration - Agricultural Research
Northwest Watershed Resarch Center
Patti Plaza - Suite 116
1175 So. Orchard
Boise, ID 83705
208-334-1363

USDA - Science Education Administration - Agricultural Research
Kimberly, ID 83341
208-423-5582

Intermountain Forest and Range Experiment Station
Research Work Unit
USDA - Forest Service
316 East Myrtle Street
Boise, ID 83706
208-334-1457

Montana State University
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Bozeman, MT 59717

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Appendix III

IDAHO DEPARTMENT OF WATER RESOURCES

Rules and Regulations
and
Minimum Standards
for Stream Channel Alterations

June 1978

Further information regarding the rules and regulations may be obtained from any of the following *Department of Water Resources* offices:

State Office
373 West Franklin Street
Boise, Idaho 83720

Western Regional Office
92 South Cole Road
Boise, Idaho 83705

Southern Regional Office
1041 Blue Lakes Boulevard North
Twin Falls, Idaho 83301

Eastern Regional Office
1515 Lincoln Road
Idaho Falls, Idaho 83401

Northern Regional Office
Route 5, Box 203
4055 Government Way
Coeur d'Alene, Idaho 83814

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FOREWORD

The rules and regulations herein implement the Stream Channel Protection Act passed by the Idaho Legislature in 1971. The rules and regulations were first adopted in 1973, then revised in 1975 and again in 1978.

The Idaho Water Resource Board and the Idaho Department of Water Resources periodically review and update these provisions to reflect changing technology and policies. Before the rules and regulations are revised, a public hearing is held and 20 days are allowed for public comments on the proposed changes. The revised rules and regulations in this booklet became effective following their adoption by the Board on April 12, 1978.

Within the rules and regulations are provisions for a permit system. Permits from the Department of Water Resources are required for most stream channel alterations, particularly those that require machinery to operate within the streambed. Before an applicant can begin work in a stream channel, his application must be reviewed and approved by the department, as well as several state and federal agencies, to assure that the natural environment of the stream is protected as much as possible.

The rules and regulations do not apply to alteration work done on intermittent streams. There are other exemptions to the provisions and they are described in Rule 2. The construction of dams and reservoirs is regulated by the department under separate provisions of the Safety of Dams Act.

This third printing of the rules and regulations includes new minimum standards for small suction dredges, for the placement of pipe crossings, such as water and sewer lines, and for construction of pilings, such as those for boat docks. Other minor changes were made in the rules and regulations that pertain to permit application, review, approval and enforcement.

Similar booklets are available containing other laws, rules and regulations administered by the department: licensing of well drillers, well construction standards, safety of dams, practice and procedure for hearings and other legal proceedings, geothermal resources and water rights.

STREAM CHANNEL ALTERATIONS

RULES AND REGULATIONS

AND MINIMUM STANDARDS

Rule

1. Purpose

The purpose of these rules and regulations and minimum standards is to specify procedures for processing and considering applications for stream channel alterations under the provisions of Title 42, Chapter 38, Idaho Code. They are intended to enable the Director to process, in a short period of time, those applications which are of a common type and which do not propose alterations which will be a hazard to the stream channel and its environment. It is intended that these rules and regulations and minimum standards be administered in a reasonable manner, giving due consideration to all factors affecting the stream and adjacent property.

2. Exemptions

2.1 Permits are not required under the provisions of Title 42, Chapter 38 for construction work on any existing or proposed reservoir project, including the dam, and such areas downstream as may reasonably be necessary for construction and maintenance of the dam.

2.2 Permits are not required for work within that portion of the Snake and Clearwater Rivers from the state boundary upstream to the upper boundary of the Port of Lewiston Port District as it now exists or may exist in the future.

2.3 No permit is required of a water user or his agent to clean, maintain, construct, or repair any diversion structure, canal, ditch, or lateral or to remove any obstruction from a stream channel which is interfering with the delivery of his water under a valid existing water right or water right permit.

2.4 No permit is required for removal of debris from a stream channel provided that no equipment will be working in the channel and all material removed will be disposed of at some point outside the channel where it cannot again reenter the channel.

3. **Definitions**

Alteration means to obstruct, diminish, destroy, alter, modify, relocate, or change the natural existing shape of the channel or to

Rule

3. **Definitions** *continued*

change the direction of flow of water of any stream channel within or below the mean high water mark. It includes removal of material from the stream channel and emplacement of material or structures in the stream channel.

3.2 *Stream channel* is a natural water course of perceptible extent with definite beds and banks which confines and conducts continuously flowing water. The channel referred to is that which exists at the present time, regardless of where the channel may have been located at any time in the past. For the purposes of these rules and regulations only, the beds of lakes and reservoir pool areas are not considered to be stream channels.

3.3 *Mean high water mark* is a water level corresponding to the "natural or ordinary high water mark" as defined in Section 58-104(9), Idaho Code, and is the line which the water impresses on the soil by covering it for sufficient periods of time to deprive the soil of its terrestrial vegetation and destroy its value for commonly accepted agricultural purposes.

3.4 *Continuously flowing water* means a sufficient flow of water that could provide for migration and movement of fish, and excludes those reaches of streams which, in their natural state, normally go dry at the location of the proposed alteration. Such exclusion does not apply to minor flood channels that are a part of a stream which is continuously flowing in the reach where the alteration is located. Also, such exclusion does not apply to streams which may be dry as a result of upstream diversion or storage of water.

3.5 *Applicant* means any individual, partnership, company, corporation, municipality, county, state or federal agency, or other entity proposing to alter a stream channel or actually engaged in constructing a channel alteration, whether authorized or not.

3.6 *Board* means the Idaho Water Resource Board.

3.7 *Department* means the Idaho Department of Water Resources.

3.8 *Director* means the Director of the Idaho Department of Water Resources.

3.9 *Plans* mean maps, sketches, engineering drawings, photos, work descriptions and specifications sufficient to describe the extent, nature, and location of the proposed stream channel alteration and the proposed method of accomplishing the alteration.

4. **Applications**

4.1 An application should be filed at least 60 days before the applicant

Rule

4. **Applications** *continued*

proposes to start the construction and shall be upon Form 3804 furnished by the Department. The application shall be accompanied by plans which clearly describe the nature and purpose of the proposed work.

In those cases where the applicant intends to follow the minimum standards (Rule 9), detailed plans may be eliminated by referring to the specific minimum standard; however, drawings necessary to adequately define the extent, purpose, and location of the work will still be required. Plans shall include some reference to water surface elevations and stream boundaries to facilitate review. It is most desirable to show the mean high water mark on the plans; however, any water surface or water line reference available will be helpful as long as this reference is described. (Examples: present water surface, low water, high water.)

4.2 The applicant shall submit 2 copies of all necessary plans along with the application form. When drawings submitted are of size larger than the application form, one copy of each such drawing shall be on tracing paper or other transparency material.

5. **Review**

5.1 The following items shall be among those considered by the Director prior to issuing a permit:

a) What is the purpose of doing the work?

b) What is the necessity and justification for the proposed alteration?

c) Is the proposal a reasonable means of accomplishing the purpose?

d) Will the alteration be a permanent solution and will the method used create a permanent and stable situation?

e) Will the alteration pass anticipated water flows without creating harmful flooding or erosion problems upstream or downstream?

f) What effect will the alteration have on fish habitat?

g) Will the materials used or the removal of ground cover create turbidity or other water pollution problems?

h) Will the alteration interfere with recreational use of the stream?

i) Will the alteration detract from the aesthetic beauty of the area?

j) What modification or alternative solutions are reasonably possible which would reduce the disturbance to the stream channel and its environment and/or better accomplish the desired goal of the proposed alteration?

Rule

5. Review *continued*

k) Is the alteration to be accomplished in accordance with the adopted minimum standards?

5.2 In those cases where a proposed alteration does not follow the minimum standards, a copy of the application will be sent for review to those state agencies requesting notification. The Director shall request review by the Department of Lands and may request review by other state agencies regardless of whether or not the proposed alteration will comply with the minimum standards.

6. Approval

6.1 All work shall be done in accordance with the application submitted and subject to any conditions specified on the permit.

6.2 A permit may be approved by the Director of the Department of Water Resources without review by other agencies except the Department of Lands in situations where the work is of a nature not uncommon to the particular area and where it is clear that the work will not seriously degrade the stream values. All work approved in this manner shall be accomplished in accordance with the minimum standards.

6.3 A permit which has expired may be reinstated by the Director after review by the Department of Lands and other agencies as determined by the Director.

7. **Enforcement of Act**

7.1 Section 42-3809 of the Idaho Code provides that it is a misdemeanor to violate any order of the Director. To insure proper notice to applicants who are found to be altering a stream without a permit or not in compliance with the conditions of a permit, employees of the Department designated by the Director may issue written orders (Form 3804-1) directing the applicant to cease and desist. Such orders shall be in effect immediately upon issuance and will continue in force until a permit is issued or until the order is rescinded by the Director.

7.2 Failure to comply with any of the provisions of the Stream Channel Act (Chapter 38, Title 42, Idaho Code), of any rule, regulation, or of any term or condition of a permit issued thereunder, or of any order of the Director may result in the cancellation of any permit by the Director without further notice and to seek in a court of competent jurisdiction, such civil or criminal remedies as may be appropriate and provided by law.

Rule

8. Emergency Waiver

8.1 Section 42-3808, Idaho Code, provides for waiver of the provisions of the Stream Channel Protection Act in emergency situations where immediate action must be taken to protect life or property including growing crops. The Director will not consider failure to submit an application for a stream channel alteration far enough ahead of the desired starting time of the construction work as an emergency situation.

8.2 A verbal waiver may be granted initially; however, all verbal requests for waivers shall be confirmed by the applicant in writing within 15 days of any initial authorization to do work. If the applicant is unable to contact the Director to obtain an emergency waiver, he may proceed with emergency work; however, he must contact the Director as soon as possible thereafter. Proving that a bonafide emergency did actually exist will be the responsibility of the applicant.

8.3 Work authorized by an emergency waiver shall be limited to only that which is necessary to safeguard life or property, including growing crops, during the period of emergency.

8.4 The applicant shall abide by all conditions set by the Director as part of this waiver.

8.5 The Director may delegate the authority to grant waivers to designated employees of the Department. Names and telephone numbers of such employees will be made available to any interested applicant upon request.

9. **Minimum Standards**

These standards are intended to cover the ordinary type of stream channel alteration and to prescribe the minimum conditions for approval of such construction. Unless otherwise provided in a permit, these standards shall govern all stream channel alterations in this state. An applicant should not assume that because his application utilizes methods set forth in these standards it will automatically be approved in all instances.

These minimum standards include the following items:

9.1 – Construction Procedures
9.2 – Dumped Rock Riprap
9.3 – Wire-Enclosed Gabion Riprap
9.4 – Sacked Concrete Riprap
9.5 – Dikes and Levees
9.6 – Jetties
9.7 – Culverts and Bridges

Rule

9. **Minimum Standards** *continued*

9.8 – Removal of Sand and Gravel Deposits
9.9 – Suction Dredges
9.10 – Piling
9.11 – Pipe Crossings

9.1 Construction Procedures. Construction shall be done in accordance with the following procedures unless specific approval of other procedures has been given by the Director. When an applicant desires to proceed in a manner different from the following, such procedures should be outlined on the application.

a) No construction equipment shall be operated below the existing water surface without specific approval from the Director except as follows: Fording the stream at one location only will be permitted unless otherwise specified; however, vehicles and equipment will not be permitted to push or pull material along the streambed below the existing water level. Work below the water which is essential for preparation of culvert bedding or approved footing installations shall be permitted to the extent that it does not create unnecessary turbidity or stream channel disturbance. Frequent fording will not be permitted in areas where extensive turbidity will be created.

b) Any temporary crossings, bridge supports, cofferdams, or other structures that will be needed during the period of construction shall be designed to handle high flows that could be anticipated during the construction period. All structures shall be completely removed from the stream channel at the conclusion of construction and the area shall be restored to a natural appearance.

c) Care shall be taken to cause only the minimum necessary disturbance to the natural appearance of the area. Streambank vegetation shall be protected except where its removal is absolutely necessary for completion of the work.

Any vegetation, debris, or other material removed during construction shall be disposed of at some location out of the stream channel where it cannot reenter the channel during high stream flows.

All new cut or fill slopes that will not be protected with some form of riprap shall be seeded with grass to prevent erosion.

d) All fill material shall be placed and compacted in horizontal lifts except as provided for in Rule 9.5 for uncompacted dike and levee construction. Areas to be filled shall be cleared of all vegetation, debris and other materials that would be objectionable in the fill.

Rule

9. Minimum Standards *continued*

e) The Director may limit the period of construction as is necessary to minimize serious conflicts with fish migration and spawning, recreation use, etc.

9.2 Dumped Rock Riprap

a) Riprap must be placed on a compact and stable embankment.

b) Sideslopes of riprap shall not be steeper than 2:1 (2′ horizontal to 1′ vertical) except at ends of culverts and at bridge approaches where a 1½:1 sideslope is standard.

c) The minimum thickness of the riprap layer shall equal the dimension of the largest size riprap rock used or be 18 inches, whichever is greater. When riprap will be placed below water, the thickness of the layer shall be 50 percent greater than specified below.

d) Riprap protection must extend at least one foot above the anticipated high water surface elevation in the stream; however, in no case will riprap be required to extend above the elevation of the top of the bank.

e) Rock for riprap shall consist of sound, dense, durable, angular rock fragments, resistant to weathering and free from large quantities of soil, shale, and organic matter. The length of a stone must not be more than three times it width or thickness. Rounded cobbles, boulders, and streambed gravels are not acceptable as dumped riprap.

f) Riprap size and gradation are commonly determined in terms of the weight of riprap rock. The average size of riprap rock must be at least as large as the maximum size stone that the stream is capable of moving. The maximum size of riprap rock used shall be 2 to 5 times larger than the average size.

There are many methods used for determining the gradation of riprap rock. One of these many acceptable methods is shown in Table 1 and Figure 1.

g) A blanket of filter material must be placed between the riprap layer and the bank in all cases where the bank is composed of erodible material that may be washed out from between the riprap rock.

Filter material shall consist of a layer of well-graded gravel and coarse sand at least six inches thick.

h) Some suitable form of toe protection shall be provided for all riprap located on erodible streambed material.

Various acceptable methods of providing toe protection are shown in Figure 2.

In addition to the approved methods of providing toe protection as shown in Figure 2, any other reasonable method will be considered by

Rule
9. Minimum Standards *continued*

TABLE 1. Gradation of Riprap in Pounds		
Max. Weight of Stone Required (lbs.)	Min. and Max. Range in Weight of Stones (lbs.)	Weight Range of 75 Percent of Stones (lbs.)
150	25 – 150	50 – 150
200	25 – 200	50 – 200
250	25 – 250	50 – 250
400	25 – 400	100 – 400
600	25 – 600	150 – 600
800	25 – 800	200 – 800
1000	50 – 1000	250 – 1000
1300	50 – 1300	325 – 1300
1600	50 – 1600	400 – 1600
2000	75 – 2000	600 – 2000
2700	100 – 2700	800 – 2700

the Director during review of a proposed project.

i) Riprap shall extend far enough upstream and downstream to reach stable areas, unless protected against undermining at ends by the method shown in Figure 3.

On extremely long riprap sections, it is recommended that similar cutoff sections be used at several intermediate points to reduce the hazard that would be created if failure of the riprap occurred at any one location.

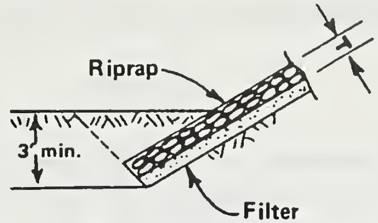
j) Placement shall result in a smooth, even finished surface. Compaction is not necessary.

The full course thickness of the riprap shall be placed in one operation. Dumping riprap long distances down the bank or pushing it over the top of the bank with a dozer shall be avoided if at all possible. Material should be placed with a backhoe, loader, or dragline. Dumping material near its final position on the slope or dumping rock at the toe and bulldozing it up the slope is a very satisfactory method of placement, if approval is obtained for the use of equipment down in the channel.

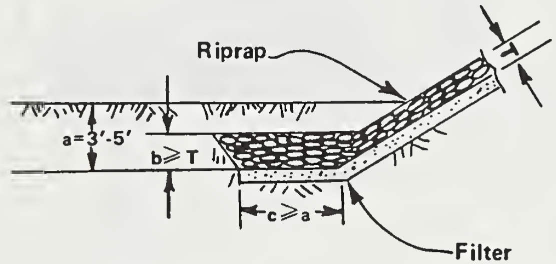
9.3 Wire Enclosed Gabion Riprap. This protection consists of filling wire "cages" with available rock and securing individual cages together to form a stable slope protection. Aesthetics can be improved by

FIGURE 1. Maximum stone size for riprap for sideslope no steeper than 1½:1

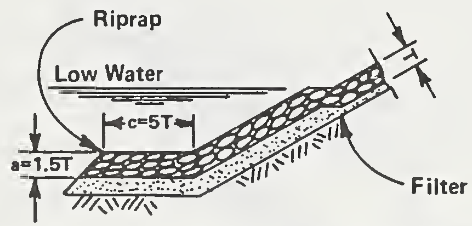
Source: U.S. Soil Conservation Service "Engineering Field Manual," 1969.



METHOD 1: This is most suited to areas where the toe is dry during construction.

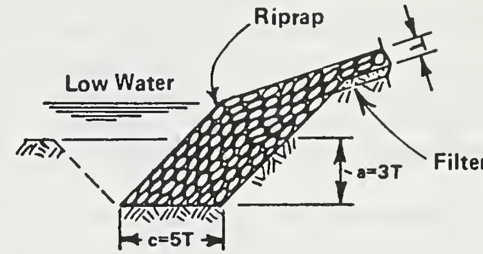


METHOD 2: Used when streambed is very wet or ground-water present makes using Method 1 impractical.

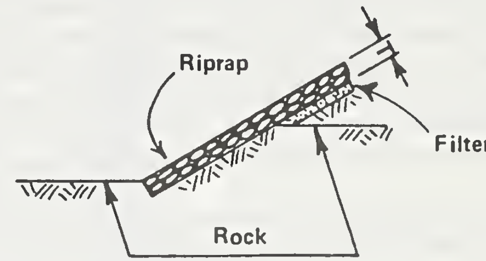


METHOD 3: Often used when toe is underwater during construction. Both Methods 2 and 3 utilize the idea that undermining will cause rock at toe blanket to settle into eroded area providing protection during scouring.

FIGURE 2. Acceptable toe protection

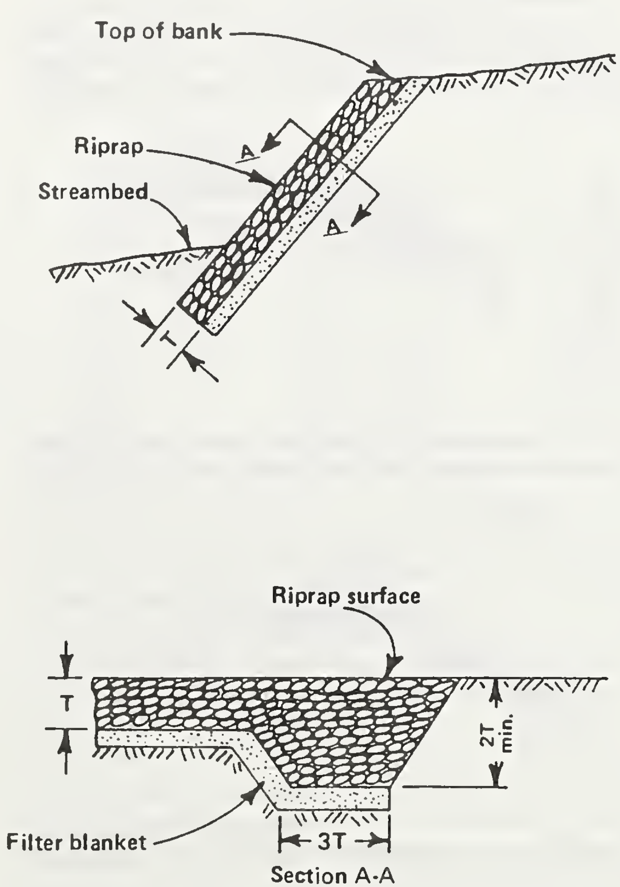


METHOD 4: Used underwater in areas with extremely bad streambed erosion conditions which make Method 3 un-feasible. This method may also be preferred where Method 3 would destroy fish spawning beds.



METHOD 5: When the streambed is non-erodible, no special provisions for toe protection are needed other than insuring that the riprap is well keyed to the rock.

FIGURE 2. Acceptable toe protection *continued*



View shown above is cross section at end of riprap looking down along the sideslope toward streambed.

FIGURE 3. Protection against undermining

Rule

9. Minimum Standards *continued*

arranging the individual gabions in a manner that will allow planting of vegetation.

9.3.1 Gabions shall be placed on a well-compacted and stable embankment.

9.3.2 In general, toe protection shall consist of protection equivalent to at least one of the following:

a) Extend gabions, on slope, at least 3 feet below streambed or to non-erodible material.

b) Extend gabions out from toe along streambed of an erodible channel a horizontal distance of at least five times the thickness of the gabion mattress.

9.3.3 Gabions may be placed to form either a mattress or a retaining wall as shown in Figures 4 and 5. Minimum thickness of mattress shall be 12 inches unless otherwise approved by the Director. Gabion retaining walls shall be constructed in accordance with the illustrated criteria as shown in Figure 5 and shall have a minimum horizontal thickness of 3 feet. Fill above gabion retaining walls shall not exceed a slope of 1½:1. Retaining walls shall not exceed a height of 10 feet above streambed unless the Director has approved detailed design plans for the project.

The wall must be founded on a stable non-erodible base unless a mattress is provided to prevent undermining as shown in Figure 6.

9.3.4 Gabions are to be of single unit construction - the base, ends, and sides to be woven into a single unit.

a) Wire. Wire mesh shall be heavily galvanized steel woven wire no smaller than 12 gage. Mesh size shall be coordinated with rock gradation as specified in Rule 9.3.5. All ties, hog rings, lacing and other wire used shall be 9 gage galvanized wire unless otherwise approved.

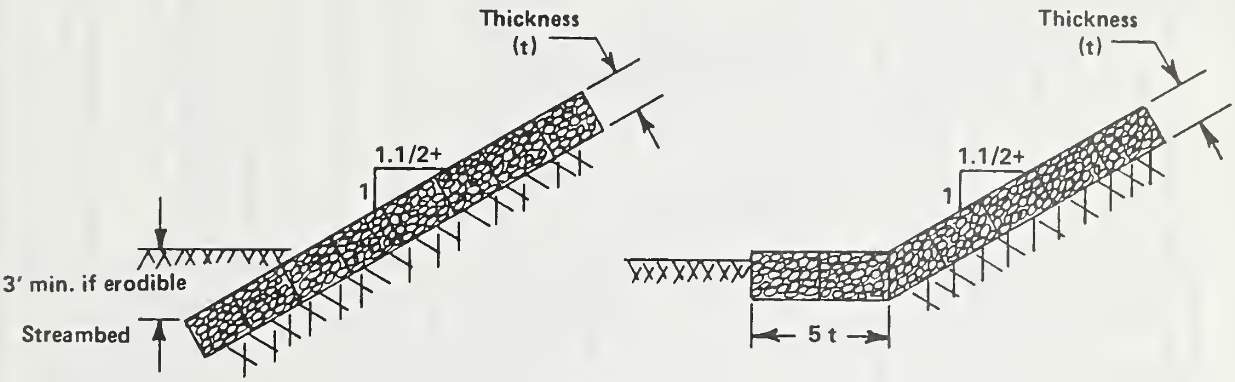
b) Size of Gabion. No individual compartment within a gabion shall have a length, width, or height exceeding 4 feet except that gabion mattress sections 1 foot or less in thickness may have a horizontal length up to 6 feet.

c) Seams. Gabion baskets shall have corners tied or laced together at least every 8 inches along edges.

d) Ties Between Gabion Baskets. At least 2 ties shall be made between gabions for every square foot of contact area.

9.3.5 Rock used for gabion fill shall be sound, dense, durable rock which is free from earth, and organic matter. The maximum size of the rock shall not exceed the gabion thickness and 70 percent of the rock by weight must exceed, in least dimension, the mesh opening in the wire.

FIGURE 4. Mattress construction



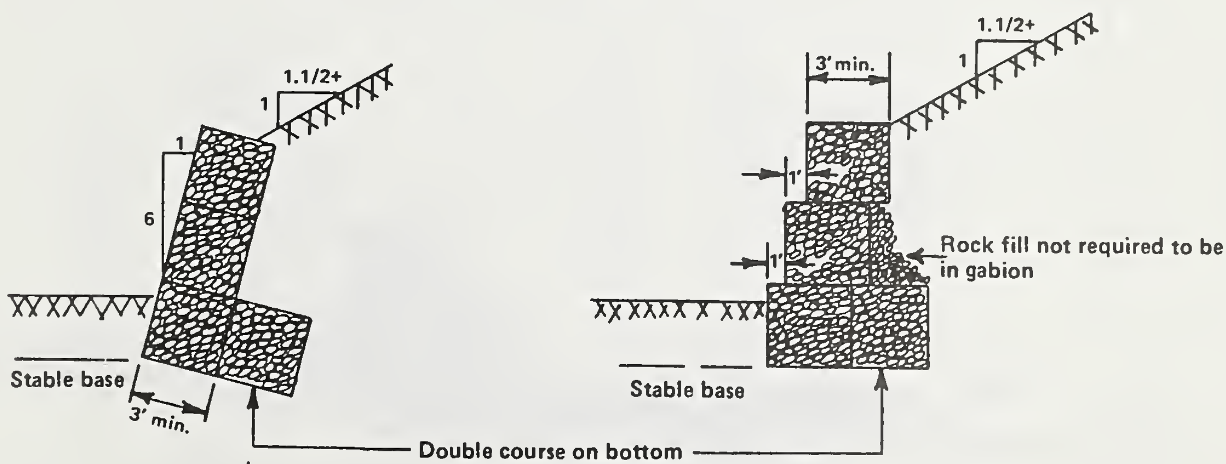
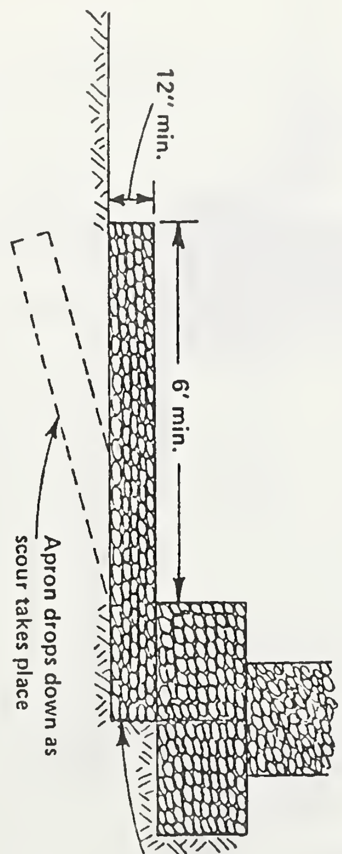


FIGURE 5. Retaining wall construction

FIGURE 6. Placement of mattress toe protection



Rule

9. Minimum Standards *continued*

9.3.6 A filter blanket of well-graded gravel and coarse sand at least 6 inches thick shall be placed between the bank and the gabions in cases where the bank is composed of fine erodible material.

9.3.7 Riprap protection must extend at least one foot above the anticipated high water surface elevation in the stream; however, it is not required that protection be extended above the elevation of the top of bank.

9.3.8 Whenever it is necessary to locate the ends of gabion protection in areas that may be subject to erosive damage, minimum cutoffs shall be provided to prevent undermining as shown in Figure 7. Views shown are cross-sections at end of gabion section looking down along the sideslope of the channel.

9.4 Sacked Concrete Riprap. This form of protection is not flexible; so compaction of the embankment and foundation and provisions for adequate toe protection are extremely important.

9.4.1 Sacked concrete riprap shall consist of approximately 2/3-cubic foot of concrete in a burlap bag or cloth cement sack. Tops of cement sacks shall be tied, and tops of burlap bags shall be folded around bag. Concrete for sacked concrete riprap shall contain at least 3½ bags of cement per cubic yard.

9.4.2 Sacks may be placed both as "headers" and "stretchers."

a) A header is a sack placed such that its long dimension is at right angle (perpendicular) to the bank providing a "thick" cross-section.

b) A stretcher is a sack placed such that its long dimension is parallel to the bank.

9.4.3. Sideslopes used for sacked concrete riprap are normally 1½:1 (1½ horizontal to 1 vertical).

a) For slopes of 1½:1 or steeper, sacks shall be placed as indicated in Figure 8.

b) For slopes flatter than 1½:1, all sacks above the bottom double row of stretchers shall be headers.

c) When the slope is steeper than 1:1, sacks shall be pinned together by driving 18" steel bars (No. 4 reinforcing steel is adequate) through each course into lower courses at intervals of at least every 6 feet along the course.

9.4.4 This type of riprap requires that a well-graded filter blanket at least 6 inches thick be used behind all installations that are not against permeable bank material. Near the bottom of the wall (above streambed) weephole openings of at least 3 square inch area shall be provided at least every 10 feet to provide drainage.

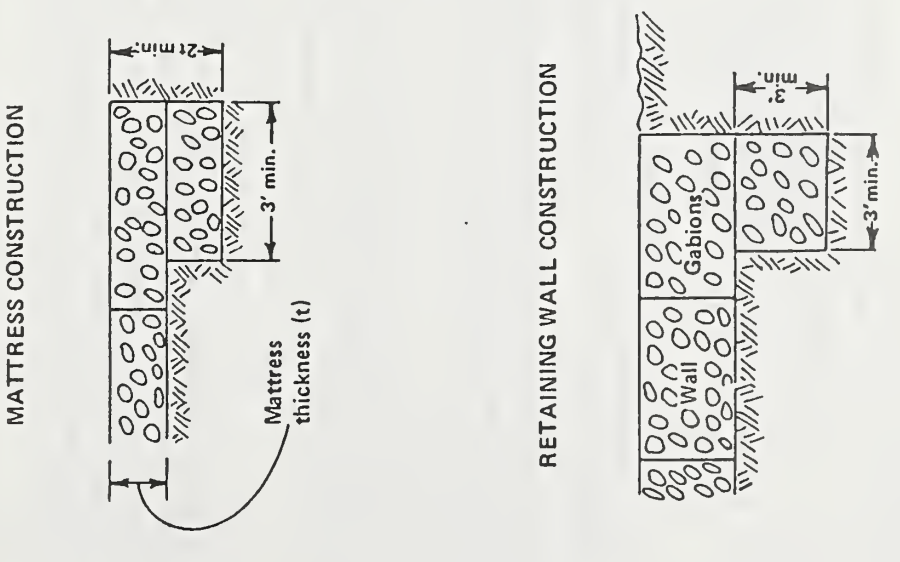


FIGURE 7. Minimum cutoffs — views shown are cross-sections at end of gabion section looking down along the sideslope of the channel

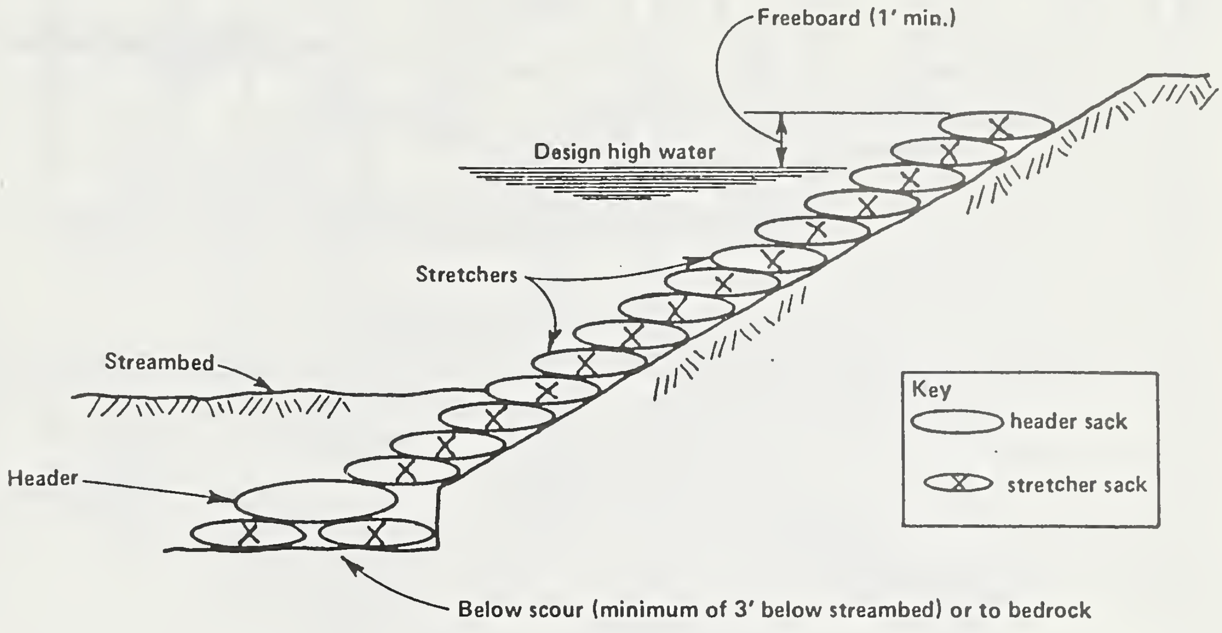


FIGURE 8. For slopes of 1½:1 or steeper

Rule

9. Minimum Standards *continued*

9.4.5 Whenever it is necessary to locate the ends of sacked concrete riprap in erodible material, provisions shall be made to prevent undermining. Such end protection shall be at least 3 feet wide and extend at least 3 feet into the streambank or below the streambed unless otherwise specified by the Director. (See Figure 9. Sacks placed to prevent undermining, shown below.)

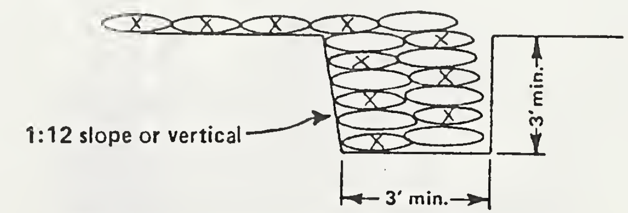


FIGURE 9. Sacks placed to prevent undermining

9.4.6 Sacks shall be placed with joints along successive courses staggered and no individual sacks shall protrude more than 3 inches from the finished surface (see Figure 10 below).

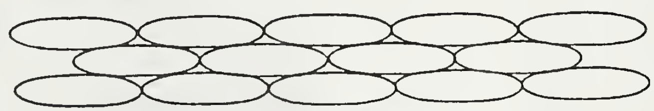


FIGURE 10. Detail of placement of sacks

9.5 Dikes and Levees. The following standards apply for dikes with heights from ground level to water surface elevation no greater than 12 feet. Approval of higher dikes will be based on evaluation of a detailed design for the particular proposal. It should be emphasized that permits for such structures are needed only when all or part of the structure is located below the mean high water mark (see Figure 11).

9.5.1 Dikes should be located in the best possible foundation material available and shall not obstruct the natural flow of or raise the water surface in the channel.

9.5.2 The drawing shown in Figure 12 indicates the most desirable location for a dike, because such an alignment results in minimum erosion and

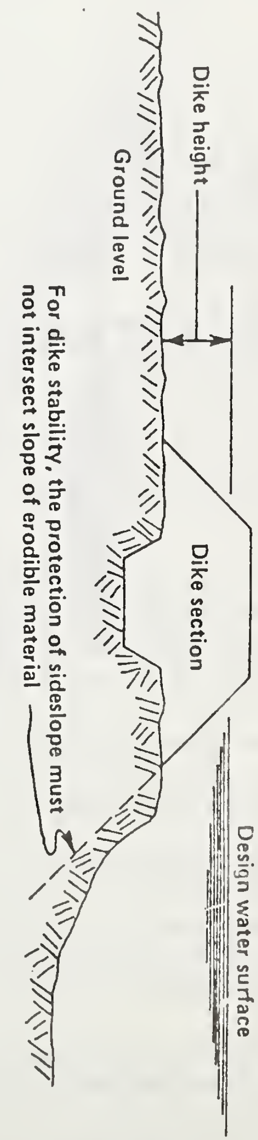


FIGURE 11. Dike cross-section

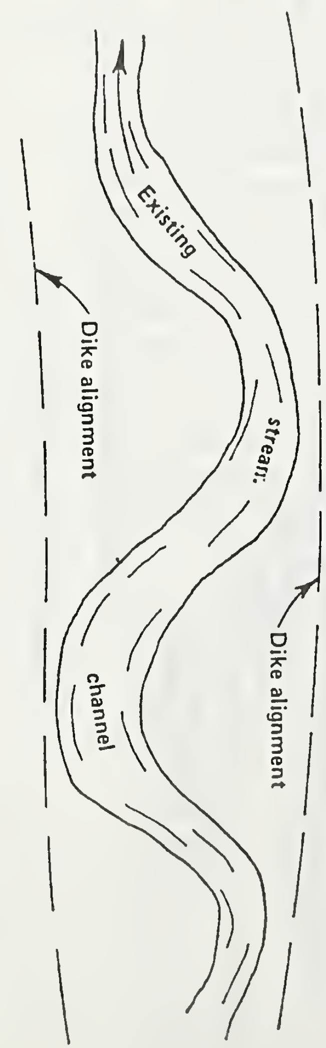


FIGURE 12. Desirable dike location

Rule

9. Minimum Standards *continued*

maintenance for the dike and the least possible disturbance to the stream; however, each applicant must decide what alignment is most suited to solving his particular problem.

9.5.3 Dike or levee foundation areas shall be clear of all trees, brush, stumps, logs, roots, boulders and other objectionable material which would interfere with scarifying the area.

a) Organic soils shall be removed except where fill used for the levee will consist of primarily organic material.

b) Unsuitable material at old channel crossings shall be removed and banks of the old channel shall be no steeper than 1:1 before fill is placed.

9.5.4 When the foundation is pervious enough that piping may occur, a core trench shall be constructed down to an impervious layer or to some reasonable depth if impervious material is not present.

a) The cutoff trench shall be located approximately along the centerline of the dike.

b) When impervious material is not encountered in the trench, drains shall be provided on the land side of the trench (use a graded sand-gravel filter blanket) and the minimum trench depth shall be as follows to insure stability:

Design Water Surface Above Ground Level	Min. Trench Depth Below Ground Level
0 – 6′	3′
6 – 12′	6′

c) The width of the bottom of the core trench shall be adequate to allow movement of construction equipment used for placing and compacting material and sideslopes of the trench shall not be steeper than 1:1.

d) Trench backfill shall consist of the most impervious material available and shall be well compacted.

9.5.5 All existing drains entering the channel shall be maintained by installing conduits through dikes.

Conduits shall be installed on firm foundations and backfill material shall be thoroughly compacted in lifts.

9.5.6 The minimum design water surface elevation that shall be provided for is similar to that required for culvert crossings and is as follows:

Rule

9. Minimum Standards *continued*

Drainage Area	Design Flow Frequency
Less than 10 sq. mi.	10 years
10 to 50 sq. mi.	25 years
Over 50 sq. mi.	50 years or greatest flow of record, whichever is more

The dike shall provide at least 2 feet of freeboard above the design water surface.

It should be noted that this flow criteria is only a minimum.

9.5.7 The height of a dike or levee shall be increased during construction enough to insure the required freeboard after settlement. Minimum height increases are as follows:

Fill Material	Minimum Height Increase
Normal compacted fill	5%
Uncompacted dragline construction	20%
Near-saturated organic matter	40%

9.5.8 Compacted mineral soil having a high specific gravity and capable of achieving low permeability is the most desirable fill material and may be utilized on all dikes or levees.

Organic fill material shall not be used on levees having a design water surface more than 6 feet above land surface, unless specific approval from the Director is obtained.

Silty or sand material shall not be used for fill unless provisions are specified on the application and/or plans which will adequately protect this material from erosion.

9.5.9 The cross-section of a dike or levee shall conform to the minimum criteria as shown in Table 2 on page 24 and Figure 13 on page 25.

9.5.10 In those instances where the location of a dike or the nature of the fill material is such that erosion of the fill is likely, some suitable form of slope protection such as riprap or grass shall be provided.

(See the appropriate riprap specification for standards required. Embankments constructed of silty or sandy materials shall receive particular attention with regard to slope protection.)

9.6 Jetties. Use of jetties shall not be permitted on curves having less than a 200 foot radius unless hydraulic analysis can be provided to show that they will achieve the desired results.

Rule
9. Minimum Standards *continued*

TABLE 2. Minimum Criteria for Dike or Levee Cross-Section

Height to Design Water Surface	Min. Top Width	Steepest Allowable Sideslope
Compacted mineral fill:		
0 – 6′	6′	1½:1
over 6′ – 12′	8′	2:1
Silty, sandy, or organic fill:		
0 – 6′	8′	2:1
Dumped, uncompacted fill:		
0 – 6′	6′	2:1
over 6′ – 12′	8′	2½:1 (Or 3:1 on stream side and 2:1 on land side.)
When road on top: (turnaround areas also needed)	10′	
Where fill unstable during rapid drawdown or severe wave action anticipated:		3.1 on stream side
Permeable soil of low plasticity used:		3:1

Jetties shall not extend into the stream from the bank more than 20 percent of the channel width unless it can be demonstrated that no undesirable effects will be created.

Jetties shall be spaced close enough together to provide continuous protection along the streambank unless other provisions for protection between the jetties are provided. Figure 14 shows one method of locating jetties.

9.6.1 The height shall be at least equal to the design streamflow depth unless the jetty is specifically designed for fish shelter or streambank toe protection only. See details in Figure 15.

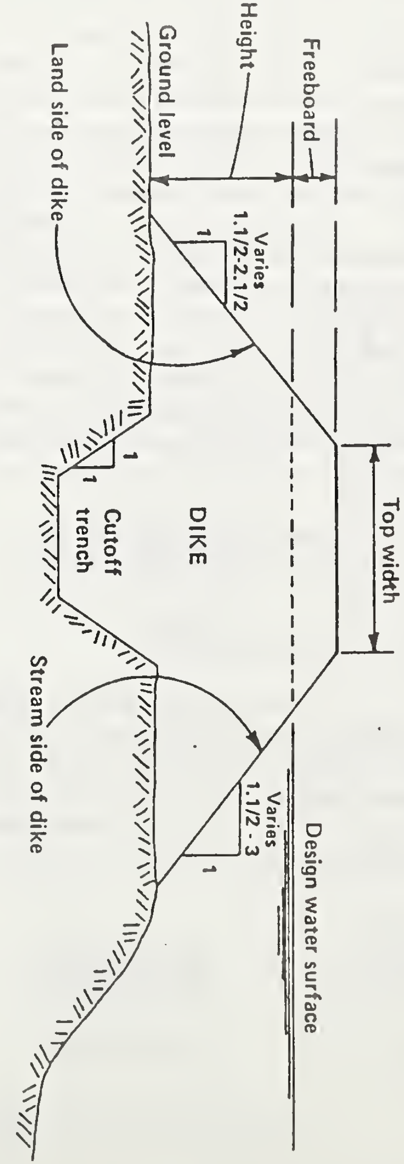
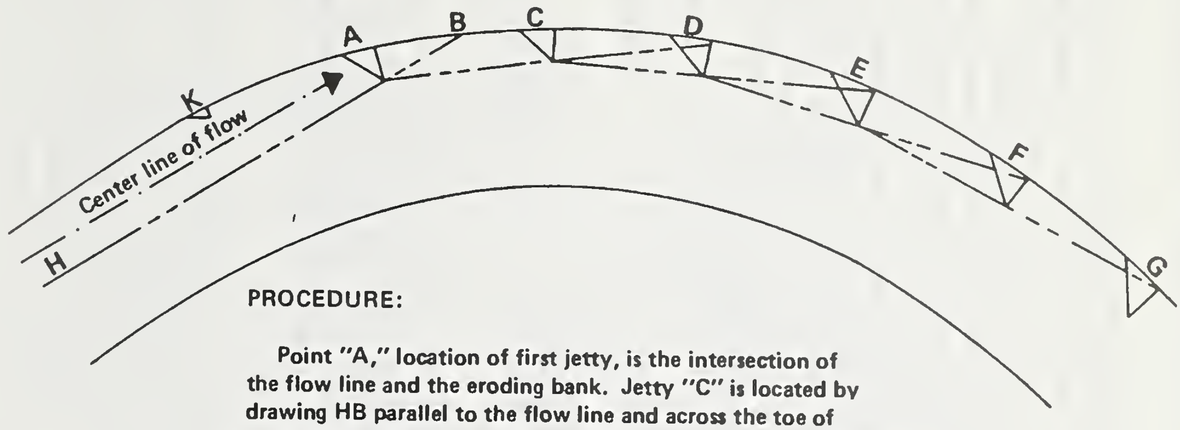


FIGURE 13. Minimum criteria for dike or levee cross-section

FIGURE 14. Method of locating jetties



PROCEDURE:

Point "A," location of first jetty, is the intersection of the flow line and the eroding bank. Jetty "C" is located by drawing HB parallel to the flow line and across the toe of jetty "A." AC is twice AB. Jetty "D" is located by projecting a line across the toe of jetties "A" and "C." The remaining jetties are located the same as "D." Supplementary jetty "K" located AC distance upstream from "A."

Source: U.S. Department of Agriculture Soil Conservation Service

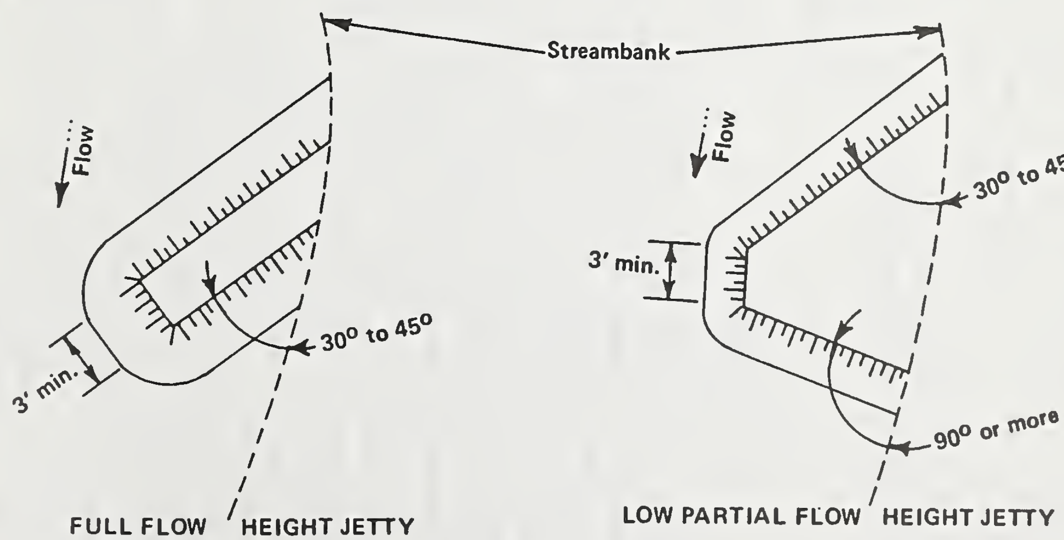


FIGURE 15. Jetty height in relation to streamflow depth

Rule

9. Minimum Standards *continued*

Jetties shall always be protected from erosion at their contact with the bank and streambed by extending the fill and/or riprap down to non-erodible material or beyond the maximum anticipated scour depth. The minimum scour depth considered shall be two feet.

Minimum top width for a jetty shall be three feet unless otherwise specified by the Director.

The steepest allowable sideslopes for a jetty shall be as follows unless otherwise specified by the Director.

Type of Jetty	Max. Sideslope
Full flow height	1½:1
Low partial flow height	2:1

Jetties shall be protected from erosive damage either by placing rock riprap or other protective cover at areas subject to erosion or by constructing the jetty using a material resistant to erosion.

a) Full flow height jetties shall be protected from erosive damage on the upstream side and end.

b) Low jetties that will be subject to flow over the entire structure shall be protected from erosive damage on all exposed surfaces.

9.6.2 Jetties may be constructed as either pervious or impervious fills.

a) Construction of a pervious jetty will require the use of fill material such as well-graded angular rock which will not be eroded or otherwise weakened by allowing seepage to flow through it. Rock filled wire gabions are also suitable for construction of pervious jetties where angular rock of adequate size is not available.

b) Impervious fill shall be placed in horizontal lifts and thoroughly compacted. Fill consisting of primarily silty material shall not be used. This type of construction requires the use of rock riprap or other suitable protection in areas subject to erosive action.

9.7 Culverts and Bridges. Culverts and bridges must be capable of carrying streamflows and must not significantly alter conditions upstream or downstream by causing flooding, turbidity, or other problems. The appearance of such installations must not be unsightly or detract from the natural surroundings of the area.

9.7.1 Culverts and bridges should be located so that a direct line of approach exists at both the entrance and exit.

Abrupt bends at the entrance or exit shall not exist unless suitable erosion protection is provided.

Rule

9. Minimum Standards *continued*

9.7.2 The ideal gradient (bottom slope) is one which is steep enough to prevent silting but flat enough to prevent scouring due to high velocity flows. It is often advisable to make the gradient of a culvert coincide with the average streambed gradient.

Where a culvert is installed on a slope steeper than 20 percent, provisions to anchor the culvert in position will be required. Such provisions must be included in the application and may involve the use of collars, headwall structures, etc. Smooth concrete pipe having no protruding bell joints or other irregularities must have such anchoring provisions if the gradient exceeds 10 percent.

9.7.3 The size of the culvert or bridge opening shall be such that it is capable of passing design flows without overtopping the streambank or causing flooding or other damage.

Design flows shall be based upon the following minimum criteria:

Drainage Area	Design Flow Frequency
Less than 10 sq. mi.	10 years
10 to 50 sq. mi.	25 years
Over 50 sq. mi.	50 years or greatest flow of record, whichever is more

(NOTE: When flow data on a particular stream is unavailable, it is almost always safe to maintain the existing gradient and cross-section area present in the existing stream channel. Comparing the proposed crossing size with others upstream or downstream is also a valuable means of obtaining information regarding the size needed for a proposed crossing.)

Minimum clearance shall be at least one foot at all bridges. This may need to be increased substantially in the areas where ice passage or debris may be a problem.

Minimum culvert sizes required for stream crossings:

18" diameter for culverts up to 70 feet long.

24" diameter for all culverts over 70 feet long.

In streams where fish passage is of concern, the following provisions and/or other approved criteria shall be followed to insure that passage will not be prevented by a proposed crossing.

a) Minimum water depth shall be approximately 8 inches for salmon and steelhead and at least 3 inches in all other cases.

Rule

9. Minimum Standards *continued*

b) Maximum flow velocities for streams shall not exceed those shown in Figure 16 for more than a 48 hour period. The curve used will depend on the type of fish to be passed.

c) Where it is not feasible to adjust the size or slope to obtain permissible velocities, the following precautions may be utilized to achieve the desired situation.

Baffles downstream or inside the culvert may be utilized to increase depth and reduce velocity. Design criteria may be obtained from the Idaho Fish and Game Department.

Where multiple openings for flow are provided, baffles or other measures used in one opening only shall be adequate provided that the opening is designed to carry the main flow during low-flow periods.

9.7.4 When crossings are constructed in erodible material, upstream and downstream ends shall be protected from erosive damage through the use of such methods as dumped rock or sacked concrete riprap, headwall structures, etc., and all such protection must extend below the erodible streambed and into the banks at least 2 feet unless some other provisions are made to prevent undermining.

Where fish passage must be provided, upstream drops at the entrance to a culvert will not be permitted and a maximum drop of one foot will be permitted at the downstream end if an adequate jumping pool is maintained below the drop.

Downstream control structures such as are shown in Figure 17 can be used to reduce downstream erosion and improve fish passage. They may be constructed with gabions, pilings and walls.

9.7.5 Where a multiple opening will consist of two or more separate culvert structures, they shall be spaced far enough apart to allow room to properly compact the fill between the individual structures. The minimum spacing in all situations shall be one foot.

In areas where fish passage must be provided, it is suggested that one opening be constructed to carry all low flows. This opening may be provided with low baffles which will facilitate fish passage yet not create a debris trap during high flow. Any installation of this type should be designed in cooperation with the Idaho Fish and Game Department.

9.7.6 All areas to be filled shall be cleared of vegetation, topsoil, and other objectionable material prior to placing fill. Material cleared from the site shall be disposed of above the high water line of the stream.

Fill material shall be reasonably well-graded and compacted and not contain large quantities of silt, sand, organic matter, or debris. In

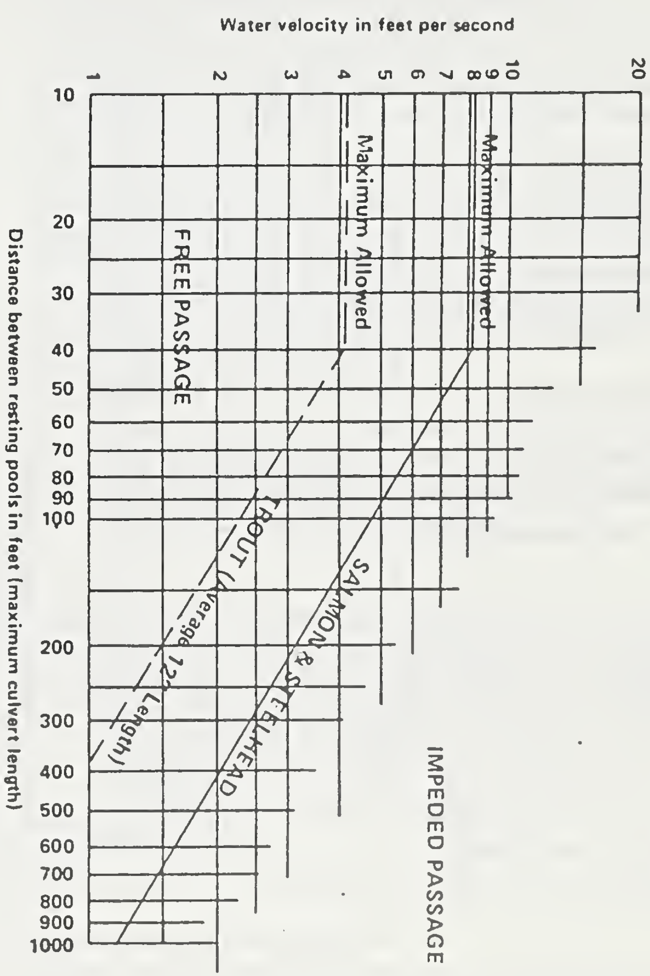
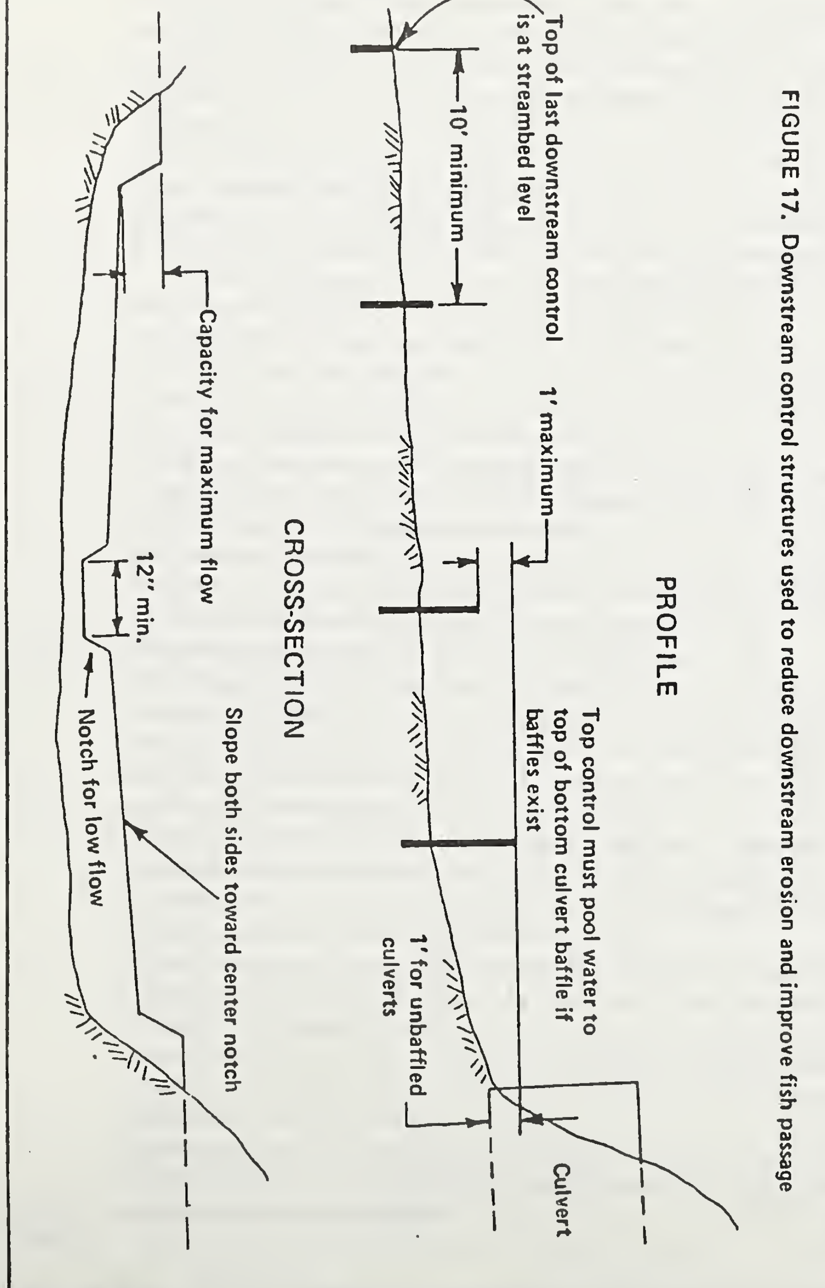


FIGURE 16. Swimming capability of migrating salmon and trout (Alaskan Curve)

FIGURE 17. Downstream control structures used to reduce downstream erosion and improve fish passage



Rule

9. Minimum Standards *continued*

locations where silty or sandy material must be utilized for fill material, it will be necessary to construct impervious sections both upstream and downstream to prevent the erodible sand or silt from being carried away (see Figure 18).

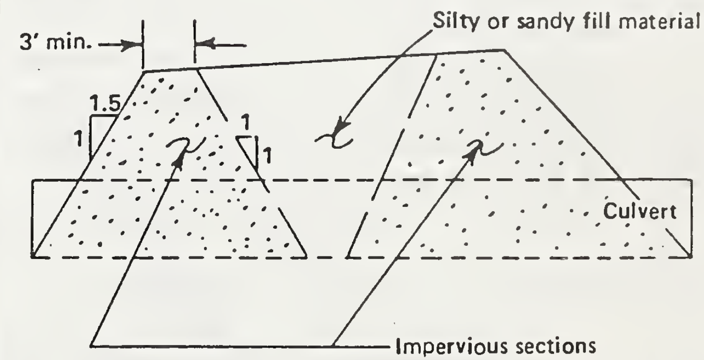


FIGURE 18. Culvert backfill using silty or sandy material

Sideslopes for fills shall not exceed 1.5:1. Minimum cover over all culvert pipes and arches shall be 1 foot.

9.7.7 All pipe and arch culverts shall be installed in accordance with the manufacturer's recommendations with regard to bedding, etc.

9.8 Removal of Sand and Gravel Deposits. This work consists of removal of sand and gravel deposits from within a stream channel. The following conditions shall be adhered to unless other methods have been specified in detail on the application and approved by the Director.

9.8.1 Sand and gravel must not be removed below the water surface existing at the time of the work. Where work involves clearing a new channel for flow, removal of material below water level will be permitted to allow this flow to occur; however, this must not be done until all other work in the new channel has been completed.

9.8.2 A buffer zone of undisturbed streambed material at least 5 feet in width or as otherwise specified by the Director shall be maintained between the work area and the existing stream. The applicant shall exercise all reasonable precautions to insure that turbidity is kept to a minimum.

Rule

9. **Minimum Standards** *continued*

9.8.3 Equipment shall be allowed to cross the existing stream in one location only, but will not be permitted to push or pull material along the streambed while crossing the existing stream.

9.8.4 Work must be done in a manner that will least disturb the natural appearance of the area. Sand and gravel shall be removed in a manner that will not leave unsightly pits or other completely unnatural features at the conclusion of the project.

9.9 Suction Dredges. The following standards shall apply only to uses of suction dredges capable of moving two cubic yards of material per hour or less.

9.9.1 A permit for the operation of a suction dredge may authorize the use of the dredge within a drainage basin or a large portion of a drainage basin except as otherwise determined by the Director.

9.9.2 There shall be no use of mechanized equipment below the mean high water mark except for the dredge itself, and any life support system necessary to operate the dredge.

9.9.3 The operation of the dredge shall be done in a manner so as to prevent the undercutting of streambanks.

9.10 Piling. The following standards apply to a piling associated with a boat or swimming dock, a log boom, a breakwater, or bridge construction.

9.10.1 In replacing a piling the old piling shall be completely removed from the channel or secured to the new piling.

9.10.2 Chemicals or compounds used on piles and lumber for protection shall be thoroughly dried to prevent bleeding, weeping or dissolution before placing such piles and lumber in or near water.

9.11 Pipe Crossings. The following standards apply to pipe crossings to be installed below the bed of a stream or river such as utility crossings of a gas line, sewer line, electrical line, communication line, water line or similar line.

9.11.1 The line shall be installed below the streambed to a depth which will prevent erosion and exposure of the line to free flowing water. In areas of high stream velocity where scouring may occur, the pipe shall be encased in concrete or covered with rock riprap to prevent the pipeline from becoming exposed.

9.11.2 The joints shall be welded, glued, cemented or fastened together in a manner to provide a water tight connection.

9.11.3 Construction methods shall provide for eliminating or minimizing discharges of turbidity, sediment, organic matter or toxic chemicals. A settling basin or cofferdam may be required for this purpose.

Rule

9. **Minimum Standards** *continued*

9.11.4 If a cofferdam is used, it shall be completely removed from the stream channel upon completion of the project.

9.11.5 Areas disturbed as a result of the alteration shall be revegetated with plants and grasses native to these areas.

10. **Hearings on Denied, Limited, or Conditioned Permit or Other Decisions of the Director**

Any applicant who is granted a limited or conditioned permit, or who is denied a permit, may seek a hearing on said action of the Director by serving on the Director written notice and request for a hearing before the Board within 15 days of receipt of the Director's decision. Said hearing will be set, conducted, and notice given as set forth in the Rules and Regulations promulgated by the Board under the provisions of Title 67, Chapter 52, Idaho Code.

11. **Appeals**

Any applicant who is aggrieved by a decision of the Board relative to the Director's decision may appeal the Board's decision to the District Court within 20 days from the issuance of such decision, as provided in Section 42-3805, Idaho Code.

12. **Forms**

12.1 Forms required by these rules and regulations.

12.1.1 Samples of all forms required by these rules and regulations are available from the Department to interested parties upon request.

12.1.2 The forms include the following:

a) Form 3804, Application for a Permit to Alter a Stream Channel; and,

b) Form 3804-1, Order to Cease and Desist Work in a Stream Channel.

Appendix IV

Excerpted from

IDAHO DEPARTMENT OF LANDS

IDAHO FOREST PRACTICES ACT, 1974,

including 1980 amendments

814.00 ROAD CONSTRUCTION AND MAINTENANCE

814.01 Purpose. Provide for road construction that will ensure adequate protection and maintenance of forest productivity, water quality, fish and wildlife habitat during construction and maintenance.

814.02 Landings. Landings shall be of minimum size and located on stable areas so as to minimize the risk of material entering streams.

814.03 Road Specifications and Plans shall be consistent with good safety practices. Plan each road to the minimum use standards adapted to the terrain and soil materials to minimize disturbance and damage to water quality.

(1) Use flexible standards to minimize damage to soil and water. Fit the road to the topography.

(2) Roads will be planned no wider than necessary to accommodate the anticipated use.

(3) Leave or re-establish areas of vegetation between roads and streams to act as a buffer strip.

(4) Design culvert installations to prevent erosion of the fill.

(5) Plan roads to drain naturally by outsloping, insloping with cross-drainage and grade changes where possible.

(6) Where justified by the volume of traffic, grade, or type of soil over which the road is built, use roadside ditches and relief culverts.

(7) Provide dips, water bars, and/or cross drainage on all temporary roads.

(8) Install relief culverts with a minimum slope of one percent and provide a sediment-catching basin at entrance of each culvert. Use slope protection measures to avoid erosion of fill areas.

(9) Avoid excessive sidehill cuts and fills near stream channels. Specify cut and fill slopes at or less than the normal angle of repose.

(10) All culvert installations on streams shall provide for fish passage.

814.04 Road Construction. Place debris, overburden, and other materials associated with road construction in such a manner as to prevent entry into streams.

(1) Deposit excess material in stable locations above the highwater mark.

(2) Clear drainage ways of all debris denerated during construction and/or maintenance which potentially interferes with drainage or water quality.

(3) Where exposed material is potentially unstable or erodible, stabilize by use of seeding, compacting, rip-rapping, benching, mulching or other suitable means.

(4) In the construction of road fills, compact the material to reduce the entry of water, minimize erosion, and minimize settling of fill material.

(5) Construct stream crossings to provide a minimum disturbance to banks and existing channels. Remove temporary crossing structures promptly after use and water bar the roads where necessary.

(6) Install drainage structures as soon as feasible. Adequately cross drain uncompleted roads, which are subject to erosion.

(7) During and following operations, retain outslope drainage and remove berms on the outside edge except those intentionally constructed for protection of road grade fills.

(8) Provide for drainage of quarries to adequately protect against sediment entering into streams.

(9) No roads will be constructed in stream channels.

814.05 Road Maintenance shall be sufficient to maintain a stable running surface, to keep the drainage system operating, and to protect the quality of the streams.

(1) When it is the intention of the landowner to discontinue use, the road will be left in such a state as to provide for adequate drainage and soil stabilization.

(2) Where necessary, clean culvert catch basin inlets and outlets and ditches before and during the rainy season to diminish danger of clogging and the possibility of washouts.

(3) All cutbacks and fills will be seeded to grass or otherwise treated annually until stabilized.

(4) Restore road surface crown or outslope or inslope all roads prior to the rainy season, depending on drainage system.

(5) Plan applications and apply road oil or other surface stabilizing material in such a manner as to prevent their entry into streams.

(6) Sidecast debris or slide material associated with road maintenance in such a manner as to prevent their entry into streams.

BEST MANAGEMENT PRACTICES

for

ROAD ACTIVITIES

Volume II:

BMP catalogue

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August 1982

Acknowledgements

The practices presented in this handbook were compiled from various research publications and technical notes of the U.S. Department of Agriculture, U.S. Department of Transportation, and the U.S. Environmental Protection Agency. Most of the text materials were derived from two major sources: the Lake Tahoe Regional Planning Agency and an existing handbook developed by the State of West Virginia - Department of Natural Resources.

Specifications for slope stabilization and drainage were drawn from previous work performed by Idaho's Panhandle Area Council under a 208 areawide waste treatment management planning grant.

Information contained in the Vegetative Stabilization section was supplied by the Maintenance Division personnel of the Idaho Transportation Department.

Preface

This handbook is a reference document for specific practices appearing in Idaho's Best Management Practices for Road Activities - Volume I. Volume I consists of an overview of the interrelationships between water quality and road project activities within the State of Idaho. Idaho Department of Health and Welfare (IDHW) policy, guidelines and a BMP Summary chart are included. The BMP Summary chart briefly identifies recommended practices and groups them into four functional categories: soil stabilization, runoff collection and conveyance, runoff dispersion and dissipation and sediment collection. Although, these practices are recognized and approved by IDHW, design will be flexible to accomodate site specific conditions. Volume II includes supplemental information on individual practices to ensure they are designed and applied to meet the intent of State policy and BMP guidelines.

The practices described in this handbook are grouped into chapters based on the four categories mentioned. An exception to this is a special chapter on revegetation due to its wide potential application. The format used to describe individual practices includes:

- definition
- purpose
- applicability
- planning criteria/methods and materials
- maintenance and
- effectiveness

It should be recognized that for certain practices, information is not available relative to all format aspects.

Practices requiring formal design are illustrated and technical computations are located in the appendices for determining runoff, soil loss, slope configuration and maximum slope length, design of riprap - lined channels and cross drain spacings.

Practices to be applied within a stream channel (such as riprap, gabions, or culverts) should be designed and installed according to the Idaho Department of Water Resources' Stream Channel Alterations, Rules and Regulations and Minimum Standards. Specific reference to applicable sections of these standards are included in the handbook under descriptions of the individual practices. A copy of the IDWR standards can be found in Appendix III - Volume I.

Mention of trade names or commerical products within this handbook does not constitute IDHW endorsement or recommendation for use.

TABLE OF CONTENTS

LIST OF FIGURES

ILLUSTRATION REFERENCES

1 California Department of Conservation, Resources Agency, May 1978. Erosion and Sediment Control Handbook, prepared for U.S. Environmental Protection Agency (EPA #440/3-78-003), pp. 135, 136, 144, 140, 139.

2 Federal Highway Administration, Region 15, December 1978. Best Management Practices for Erosion and Sediment Control, U.S. Department of Transportation, pp. 39, 52-53, 46.

3 Megahan, Walter F. 1977. Reducing Erosional Impacts of Roads, reprinted from Guidelines for Watershed Management, FAO Conservation Guide, Food and Agriculture Organization of the United Nations, Rome (purchased by USDA Forest Service for official use), pp. 251, 257.

4 Transportation Research Board, National Research Council, 1973. Erosion Control on Highway Construction. National Cooperative Highway Research Report #18, p. 21.

All other figures were obtained from the Panhandle Area Council's "Water Quality Management Plan for North Idaho Lakes and Streams" 1978.

CHAPTER I

SOIL STABILIZATION

Contents and Applicability

BEST MANAGEMENT PRACTICES (BMP):

TEMPORARY TREATMENTS

I-1 CHEMICALS AND TACKIFIERS. The use of chemicals for dust and erosion control.

I-2 MATTING - FIBERGLASS ROVING. The use of continuous glass fibers as a mulch with a tacking agent to adhere the mulch to the surface and to itself. The mulch does not deteriorate as rapidly as other mulches.

I-3 MATTING - PLASTIC SHEET. Used for dust and erosion control during construction on bared soils. Also aids early vegetative growth by increasing moisture holding capacity of soil.

I-4 MATTING - WOOD EXCELSIOR. Used for dust and erosion control. Great care must be taken to prevent flows under the mat as bridging of the mat over rills is a common problem.

I-5 MATTING - JUTE. A mat used alone or with straw mulch or hydromulch for erosion control and slope stabilization.

I-6 MULCH - CRUSHED STONE AND GRAVEL. A temporary mulch used for dust and erosion control during construction.

I-7 MULCH - STRAW. A temporary mulch which will last from one to two years. The straw will deteriorate without detrimental effects on plant growth or establishment. It is most applicable on small sites where hand labor is used, and larger (>1 acre) sites where mechanization can be used.

I-8 MULCH - WOOD CHIPS. A temporary mulch method used for dust and erosion control or as mulch for vegetation.

I-9 MULCH - WASHED DAIRY WASTE (WDW). A temporary mulch (not commercially available) providing erosion protection and aiding vegetative growth.

I-10 MULCH BLANKET. Sheets of cellulose fibers bound together with a water soluble binder and meshed with plastic or cotton net. Binder dissolves and fibers loosen upon saturation to form a temporary mulch cover held in place by mesh net.

I-11 HYDROMULCHING (WOOD FIBER). A mechanized, rapid method for mulching steep, large areas which are close to access roads or can be reached over reasonably flat terrain.

I-12 PLASTIC NETTING. A net for mulch stabilization which must be used over a mulch, such as straw or hydromulch.

PERMANENT TREATMENTS

I-13 CELLULAR CONCRETE BLOCK REVETMENT (GOBI BLOCKS). Arrangement of concrete blocks placed in parallel adjacent rows across slope to be seeded. Generally used on small areas where a high degree of soil stabilization is necessary for vegetative success.

I-14 COMPACTION. Mechanical soil densification to reduce settling and improve resistance to erosion.

I-15 GABIONS. Rock-filled wire baskets for use in retaining walls or drainage stabilization.

I-16 RIPRAP. A permanent rock or aggregate layer placed over the soil to protect against erosive water velocities.

I-17 NATIVE ROCK RETAINING WALL. A low wall made from locally available rock used to stabilize oversteepened slopes.

I-18 REDWOOD RETAINING WALL. A low wall of posts and planks used to stabilize small, oversteepened slopes which are underlain with rigid rock base material, or very compact, nonplastic soil.

I-19 SODDING. Continuous or strip placement of cultivated sod used to stabilize soil, protect stockpiled materials, filter runoff, and dissipate energy of runoff.

I-20 SPRIGGING. A permanent revegetation technique used to achieve more rapid growth of larger vegetation.

I-21 SUBSURFACE DRAINAGE (SEEPAGE CONTROL). Systems to capture subsurface water and prevent erosion or mass wasting of the slope.

I-22 TUBELINGS. Permanent revegetation technique used for soil stabilization on soils of low productivity.

I-23 WATTLING. Permanent revegetation technique used for soil stabilization on steep slopes.

I-24 TIMING OF CONSTRUCTION AND CONTROL APPLICATION. The sequencing of construction activities and erosion control application to minimize erosion created by construction disturbance.

I-25 SURFACE AREA EXPOSURE. Limiting the area of bared soil to the minimum area required to conduct construction activities.

I-26 JUNIPER REVETMENT FOR STREAMBANK STABILIZATION. A revegetation technique for permanently stabilizing erodible streambank areas.

I-1

CHEMICALS AND TACKIFIERS

DEFINITION

Plastics, organic seeding additives, asphaltic tacking agents and other similar products used in slope stabilization.

PURPOSE

To "tack" erosion control fibers to slopes and for dust and erosion control.

APPLICABILITY

These products should be used to aid the stabilization of mulches where matting is not used and for temporary dust and erosion control on inactive construction sites.

PLANNING CRITERIA

No chemicals or tackifiers should be used if an alternative method has been demonstrated to be effective for soil stabilization in the same conditions. The appropriate applications of these compounds are limited to use upon steep and rocky slopes where neither mechanical methods nor mulches and protective netting may be effectively applied and to construction sites for temporary dust and erosion control. Careful selection of brands of products is extremely important as some have demonstrated no beneficial effect. The proposed application rate of all products should be of demonstrated effectiveness.

METHODS AND MATERIALS

All products should be applied according to the manufacturer's recommended procedure. When portions of a product must be mixed, thorough mixing should be accomplished in an appropriate container, such as a hydroseeder mixing tank.

- Fibers - When applied for temporary purposes, these agents should be mixed with 150 pounds of wood fiber per acre:
    - All plastic, resin, or other chemical soil stabilizing agents, additives and "binders" or "tackifiers" which are to be used in a permanent application with seed and mulch should be applied over wood fiber (BMP I-11) or straw (BMP I-7).

- Wood fiber may be applied by hydromulching or by blowing. Straw may be blown or hand spread. The tackifier should be sprayed onto the surface after the wood fiber or straw is in place.

- Organic Seeding Additives

    - Acceptable products should be of one of the following compositions:

        - A free-flowing powder produced from seaweed extracts, consisting of an alginase and a jelling agent. Proper mixing of these two parts is essential.

        - A natural gum derived from seeds, which becomes mucilagenous upon wetting.

    - Application should be at a rate which has been demonstrated to be effective. Manufacturer's representatives and erosion control specialists should be consulted. Seed gums should be applied according to manufacturer's specificed rates and seaweed extract powders should be applied at 90 pounds of chemical per acre.

- Plastics

    - Plastics should be used to temporarily stabilize soils exposed by construction and for specific sites which have extreme cycles of wetting and drying.

    - Acceptable products should be those of polyvinyl acetate composition. ("Soil Bond", "Enviro", or equivalent.)

    - Application rates should be 1,000 pounds of solids per acre when applied without fiber. When applied with fiber, the application rate should be 160 pounds of solids per acre and 1,000 pounds of fiber per acre.

    - When applied with seed, plastics should be applied in a second operation over the seed.

    - When applied with plastics, seeding rates should be doubled.

EFFECTIVENESS

Soil stabilizing chemicals and tackifiers can achieve 70-90 percent reduction of sediment generation for the first six months. Deterioration of these agents reduces these figures to 40-60 percent in two years, and 10-30 percent beyond two years. Nutrient reduction is estimated to be 50-70 percent, 20-50 percent and 0-10 percent for the same periods.

I-2

FIBERGLASS ROVING

DEFINITION

A matting of continuous strands of glass fibers held together with a tacking agent.

PURPOSE

Temporary soil stabilization dust and erosion control for one to three years.

APPLICABILITY

As a mulch on seeded or unseeded slopes and small drainage channels.

PLANNING CRITERIA

Slope stabilization with fiberglass roving aids in mitigating environmental changes near the ground surface and in reducing raindrop impact and over the slope runoff. It does not supply additional moisture holding capacity or organic matter as do other mulches.

METHODS AND MATERIALS

- The materials should be formed from continuous fibers drawn from molten glass, coated with chrome complex sizing compound, collected into strands and lightly bound together into roving without the use of clay, starch or other deleterious substances. Roving should be wound into cylindrical packages such that the roving can be fed continuously from the center of the package through an ejector driven by compressed air and expanded into a mat of glass fibers on the soil surface. No petroleum solvents or toxic substances should be contained in the material.

- Roving should be applied within 24 hours after the completion of normal seeding operations.

- The fiberglass roving mat should be of uniform density of randomly laid fibers at approximately 0.25 - 0.35 pounds of fiber per square yard.

- Asphaltic emulsion tacking agent or its equivalent as shown in BMP I-1 should be applied at a rate of 0.25 to 0.35 gallons per square yard to anchor the mat to the ground.

- To prevent undercutting, the uphill end of the mat should be placed in a trench 8 inches deep, which should be backfilled after roving is in place.

- The pneumatic ejector should be capable of applying the roving at a rate of two pounds per minute.
- An air compressor capable of delivering 40 CFM at 80 to 100 psi and suitable air hoses are required to drive the ejector.
- An approved distributor for the asphaltic emulsion tacking agent and all of its associated equipment is suggested.

MAINTENANCE

If the matting is damaged, it should be repaired or replaced immediately. Maintenance inspections should be made periodically, and the following procedure should be used to repair damaged areas:

- Original grade specifications should be met.
- Any seeding, planting or fertilizing should be conducted as per the original specifications.
- The fiberglass mat above the damaged area should be peeled back to expose an undamaged area at least 4 feet long upgrade from the damaged area.
- Fiberglass roving meeting the above specifications should be applied at the specified rate to the damaged area and the exposed area upgrade from the damaged area.
- The upper end of the new mat should be buried in a trench at least 8 inches deep.
- The old mat should be replaced over the new mat.
- Asphaltic emulsion should be applied at the originally specified rate over the new mat and the overlapped area of the old mat.
- In extremely unstable areas, staples as specified in BMP I-5 should be driven through the overlap area of the old and new mats. Spacing shall be 18 inches in all directions.

EFFECTIVENESS

Fiberglass roving strands are more durable than wood fiber, but tend to become broken or damaged as time elapses. Sediment generation reductions of 90-95 percent for one year, 80-90 percent for up to two years and 60-70 percent beyond two years are estimated. Nutrient reductions for these periods are 60-80 percent, 50-70 percent and 40-60 percent.

I-3

MATTING - PLASTIC SHEET

DEFINITION

Plastic sheets of polyethylene laid over the soil surface.

PURPOSE

Temporary erosion control, protection of early vegetative growth and reductions in soil moisture loss and soil temperature.

APPLICABILITY

Surface protection against erosion.

PLANNING CRITERIA

Soil stabilization using plastic sheeting reduces raindrop impact on disturbed soils. It also may aid early vegetative growth by retarding evaporation of soil moisture. Plastic sheets must be anchored to prevent wind damage. Slopes should be smoothed of rock outcroppings prior to sheet placement.

METHODS AND MATERIALS

- Application should be as specified below (similar to matting installation BMP I-4).
- Individual rolls should be applied up and down the slope rather than along the contour.
- Sides of the rolls should overlap a minimum of 4" with the uphill roll overlying the downhill roll.
- Sheeting should be stapled or buried at ends to secure placement (see BMP I-4).

MAINTENANCE

If sheeting is damaged, it should be replaced immediately. Maintenance inspections should be made periodically.

EFFECTIVENESS

The durability of polyethylene depends on sheeting thickness but generally provides erosion protection for 6 - 12 months. It is the most effective matting for retaining soil moisture.

I-4

WOOD EXCELSIOR MATTING

DEFINITION

A mat made of wood excelsior fiber bonded to a paper or plastic reinforcing net.

PURPOSE

Temporary soil stabilization, erosion control, and mulching on construction or revegetation sites.

APPLICABILITY

This method can be utilized in the following circumstances:

- Construction sites becoming temporarily inactive (inactive period greater than two weeks and less than one year).
- Graded areas receiving permanent revegetation treatment by seeding.
- Bare areas receiving permanent revegetation treatment by seeding.
- As an alternative to jute netting.

PLANNING CRITERIA

Wood excelsior matting is a heavy wood fiber net which is generally purchased in rolls and is stapled to slopes to provide a uniform covering. This covering protects mulches, provides additional water-holding capacity, and aids in moderating environmental fluctuations near the ground surface as does a mulch. Greater integrity of a mulched area results from the use of a net or mat covering than from any other single method, such as punched straw.

The soil must be reasonably smooth.. Gullies and rills must be filled and compacted. Rocks or other obstructions which rise above the level of the soil or mulch should be removed.

Due to the difficulty of placing wood excelsior matting and its less predictable results in controlling erosion, jute matting is preferred.

METHODS AND MATERIALS

- Excelsior blankets should consist of machine-produced mats of curled wood excelsior of 80 percent of which have an 8-inch or

longer fiber length. It should be of consistent thickness with the fiber evenly distributed over the entire area of the blanket. The top side of each blanket should be covered with a 3-inch by 1-inch weave of twisted Kraft paper or biodegradable plastic mesh that has a high wet strength. Blankets should be fire and smolder resistant and contain no chemical additives. Blankets shall be in 3-foot by 150-foot rolls or in 4-foot by 180-foot rolls.

- If the wood excelsior mat is to be applied without other mulches, the minimum thickness of mat should be 1-1/2 inches.

- If the wood excelsior mat is to be applied over other mulches, the minimum thickness shall be 1/2 inch.

- After site preparation and seeding (if any), the rolls of wood excelsior matting should be rolled onto the surface from the top of the slope to the bottom of the slope, never along the contour.

- The upper end of each blanket should be buried in a trench at least 8 inches deep, and the trench should be backfilled and tamped. (Refer to Figure I-5 which relates to jute mat placement.)

- Staples should be applied at 2 feet on center along the sides of the blanket and 4 feet on center along the center of the blanket.

- Blankets placed side-to-side should be snuggly butted together to prevent rilling and gullying along the joint.

- Blankets placed end-to-end should be overlapped. The top of the lower blanket should be placed in an 8-inch deep trench which should then be backfilled and tamped. The lower end of the upper blanket should be overlapped onto the lower blanket, and staples should be placed through both blankets. (Refer to Figure I-5 which relates to jute mate placement.)

- Staples should be of heavy gauge wire, 0.091 inches in diameter or greater, which have been bent into a "U" shape, with legs at least 8 inches long, and a 1-inch crown. Longer staples are required in loose or sandy soil.

EFFECTIVENESS

Due to the difficulty of proper application, wood excelsior matting has a more variable effectiveness than straw, jute or hydromulch. Properly applied, it can be as effective. Sediment reduction should range from 50-90 percent, 20-60 percent and 0-30 percent in six months, two years and beyond two years, respectively. Nutrient reductions for the same time periods are estimated to be 30-70 percent, 10-50 percent and 0-10 percent.

I-5

JUTE MATTING

DEFINITION

Mulch nets made of jute.

PURPOSE

Slope stabilization, erosion control and protection of mulches from wind or water damage.

APPLICABILITY

Jute matting can be applied over straw, wood fiber or manure mulches when wind velocities or runoff quantities and velocities indicate damage to mulches would occur without a protective net. It may be applied alone as an alternative to straw or wood fiber mulches on flat sites for dust control and seed germination enhancement, but should not be applied alone where runoff quantities are significant.

PLANNING CRITERIA

Jute netting is a heavy fiber net which is generally purchased in rolls and is stapled to slopes to provide a uniform covering. This covering protects mulches, provides additional water-holding capacity and aids in moderating environmental fluctuations near the ground surface, as does a mulch. Greater integrity of a mulched area results from the use of this covering than from any other single method, such as punched straw.

The soil must be reasonably smooth. Gullies and rills must be filled and compacted. Rocks or other obstructions which rise above the level of the soil and mulch should be removed.

METHODS AND MATERIALS

- Application should be as specified below. Care in installation is required due to the unstable nature of some soils.
- The details of installation are shown in Figure I-5.
- Jute mat should be cloth of a uniform plain weave of undyed and unbleached single jute yarn, 48 inches in width plus or minus 1 inch and weighing an average 1.2 pounds per linear yard of cloth with a tolerance of plus or minus 5 percent, with approximately 78 warp ends per width of cloth and 41 weft ends per linear yard of cloth. The yarn shall be of a loosely twisted construction having an

average twist of not less than 1.6 turns per inch and should not vary in thickness by more than 1/2 of its normal diameter.

- Individual rolls should be applied up and down the slope, never along the contour.

- Sides of rolls should overlap at least 4 inches, and rolls should have at least a 3-foot overlap when an uphill roll joins to a downhill roll. The uphill roll should overlie the downhill roll.

- Staples should be made of wire, 0.091 inches in diameter or greater, "U" shaped with legs at least 6 inches in length and a 1-inch crown. Longer staples are suggested in loose or sandy soils.

- Staples should be driven perpendicularly into the slope face, and should be spaced approximately 5 feet apart down the sides and center of the roll. Spacing between staples at the upper end of a roll or at the end overlap of two rolls should not exceed 1 foot.

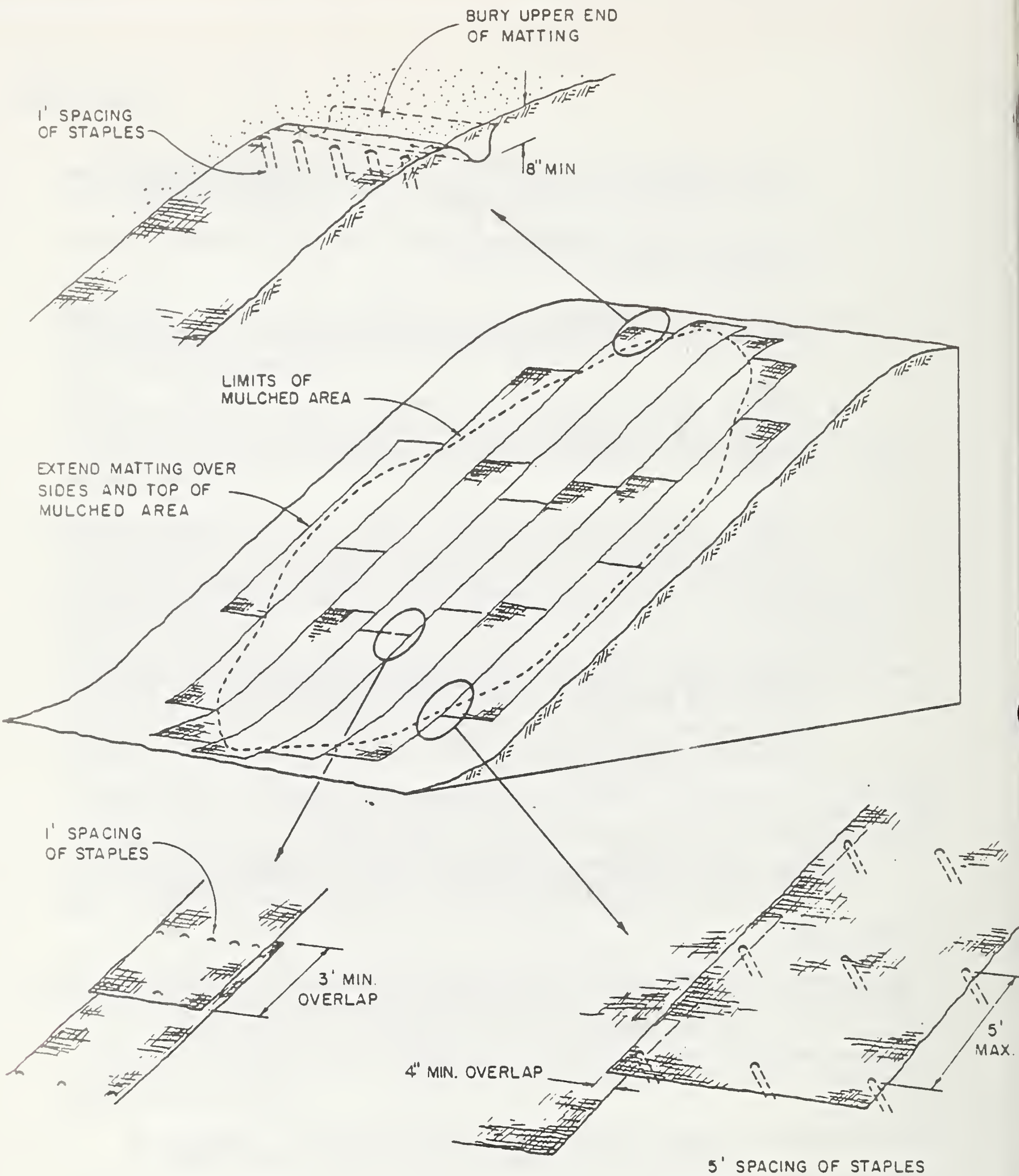
- Matting should be continued beyond the edge of the mulched or seeded area at least 1 foot at the sides and 3 feet at the top and bottom of the area. If existing vegetation or structures mark the boundaries of the area, the matting should be continued into the stable vegetated area or to the edge of the structure.

- The upper end of the matting at the top of the area should be buried in a trench at least 8 inches deep.

- The matting should make uniform contact with the slope face underneath. No "bridging" of rills or gullies should be allowed.

EFFECTIVENESS

Jute netting acts similary to straw mulch or hydromulch. Sediment reduction for up to six months is 70-90 percent, with 40-60 percent expected for up to two years, and 10-30 percent beyond two years. Nutrient reductions are estimated at 50-70 percent for six months, 20-50 percent for up to two years, and 0-10 percent beyond two years.



JUTE MATTING

Figure I-5

I-6

CRUSHED STONE AND GRAVEL MULCHES

DEFINITION

The application of gravel or crushed stone as a mulch.

PURPOSE

To stabilize soils during construction activities and for other temporary periods.

APPLICABILITY

On construction sites, low-use dirt roads, driveways and other areas of light vehicular activity.

PLANNING CRITERIA

- Gravel or crushed stone of approximately 3/4 inch to 1-1/2 inch diameter may be used interchangeably. At least 30% of the material should be larger than 3/4 inch in diameter. Apply material in a uniform covering.

- Application rates shall be at least 100 tons per acre, with a minimum acceptable surface coverage of 90 percent. If the material used does not supply 90 percent coverage at 100 tons per acre, the application rate should be increased.

- After the gravel or stone is applied, construction or other traffic may move over it. Areas which become compacted or depressed should be remulched to the same level as the remaining area to prevent flows from the site from becoming channelized into these depressions.

- Upon completion of activities on the site, the gravel or stone mulch may be left in place during revegetation operations.

- When used for driveways or dirt roads, a filter blanket should be placed under the gravel.

EFFECTIVENESS

Crushed stone and gravel mulches retain their effectiveness indefinitely if properly applied and protected from compacting traffic. Sediment reduction is estimated at 70-90 percent, and nutrient reduction at 50-70 percent.

I-7

STRAW MULCH

DEFINITION

The application of staple straw as a protective cover over bare or seeded soil.

PURPOSE

To reduce erosion and to provide a mulch for aiding revegetation.

APPLICABILITY

Used on slopes or areas which have been seeded or which may be subject to wind or water caused erosion. Straw mulch requires matting, crimping, or other methods to hold it in place.

PLANNING CRITERIA

- Straw mulch provides organic matter as it breaks down and is incorporated into the soil. If applications are too heavy, however, reduction of soil nutrient levels, especially nitrogen may occur during the period of decomposition. Therefore, application rates of both the straw mulch and the fertilizer specified should be strictly adhered to.

- Straw mulch forms a loose layer when applied over a loose soil surface. To protect the mulch from wind drifting and water damage, it must be stabilized by covering it with a netting such as jute, by punching it into the soil with a spade or roller, or by spraying it with a tacking agent.

- Straw mulch should cover the entire seeded area or exposed slope. The mulch should extend into existing vegetation or stabilized areas on all sides to prevent wind or water damage which may start at the edges of the mat.

METHODS AND MATERIALS

- On small slopes, straw mulch should be applied by hand broadcasting to a uniform depth of 2-3 inches.

- On larger slopes, straw can be blown onto the slope to achieve a uniform cover of 2-3 inches.

- The straw fibers should be applied to form a uniform mat of loose straw through which approximately 20 to 40 percent of the original ground surface can be seen. No large clumps of unscattered straw should exist after application.

- Application rate should be 2 tons of straw per acre, which will provide a 2-3 inch covering of straw on the ground surface. The maximum depth should be 3 inches except on soils subject to frost heaving where 4 inches should be applied.

- Straw should be clean rice, barley or wheat straw. Fibers should not be chopped or ground to reduce the fiber length.

- Stabilization of the mulch mat should be by one of the following methods.

  - Hand Punching - used on small sites, sites with much rock and stone on the surface, sites with slopes which are steeper than 3:1, or sites which have been wattled. Care must be taken not to damage wattling or planted vegetation. A spade or shovel should be used to punch the straw into the slope until all areas have straw standing perpendicularly to the slope and embedded at least 4 inches into the slope. The bunches of straw should resemble the tufts of a toothbrush.

  - Roller Punching - used on large, gently sloping sites without significant outcroppings of rock and stone. Roller punching should not be used on sites which have been wattled unless adequate space between lines of wattling is available, or on vegetatively planted sites. A roller equipped with straight studs not less than 6 inches long, from 4 to 6 inches wide, and approximately 7/8 inch thick, will best accomplish the desired effect. Studs should stand approximately 8 inches apart and should be staggered. All corners should be rounded to prevent withdrawing the straw from the soil. Rollers should not be used to punch straw on slopes which have been wattled or vegetatively planted. Vegetative planting may be conducted following roller punching.

  - Crimper Punching - specially designed straw crimping rollers are available for use wherever roller punching can be used. These crimpers consist of serrated disk blades set 4 to 8 inches apart which force straw mulch into the soil. Crimping should be done in two directions with the final pass conducted across the slope rather than up and down it.

  - Tacking Agent - to be used on any type of site, but best used only on very stony or rocky soils or small, steep slopes. Two hundred gallons per acre of asphaltic tacking agent or its equivalent should be applied over the straw mulch. Agents which are neutral or nearly neutral in color and of demonstrated effectiveness in the soils and climate of the area in question are acceptable.

- Matting - to be used on large, steep areas which cannot be punched with a roller. Jute or wood excelsior on plastic netting shall be applied over unpunched straw according to BMP I-4, 5, or 12.

EFFECTIVENESS

Straw mulches react similarly to hydromulches, as they break down fairly rapidly. However, straw is twice as effective and at about half the cost of hydromulches. Sediment generation reduction from straw mulch without vegetation is from 90-95 percent for a few months, but drops off to 70-90 percent in six months, and further to 40-60 percent in two years, and 10-30 percent after that. Nutrient reductions are estimated at 60-80 percent for a few months, 50-70 percent in six months, 20-50 percent up to two years and 0-10 percent beyond two years.

WOOD CHIP APPLICATION

DEFINITION

Temporary mulch and surface protection using chips of wood.

PURPOSE

Slope stabilization for a period of one month to three or four years.

APPLICABILITY

Wood chip applications are useful for temporary dust and erosion control during construction, and for mulching around vegetative plantings.

PLANNING CRITERIA

- Wood chips should be prepared by processing tree trunks and branches in a wood chipper, and should be machine blown or hand spread to a uniform depth of approximately 3 inches. Chip sizes should be: width, from 1/2 inch to 1-1/2 inch; length, 1/2 inch to 1-1/2 inch; thickness, 1/8 inch to 1/2 inch. Chips from kiln dried or air dried material should not be utilized.

- Due to bacterial action during decomposition, nutrient concentrations in the soil may be depressed under a layer of wood chips. Because of this, applications should not exceed the specified thickness, which would cause a marked depression in some soil nutrients for longer periods.

- Wood chips are used to mulch revegetation projects. The specified application of fertilizer should be increased approximately 25 percent to replenish soil nutrients lost due to breakdown of wood chips.

MAINTENANCE

Slopes should be inspected for damage by wind, water or human disturbance periodically throughout the year. Damaged areas should be repaired immediately according to original specifications.

EFFECTIVENESS

Wood chips deteriorate more slowly than wood fiber and therefore retain their effectiveness longer. Sediment generation reductions of 90-95 percent can be expected for a year, 80-90 percent up to two years, and 50-60 percent beyond two years. Nutrient reductions of 60-80 percent, 50-70 percent, and 30-50 percent are estimated for the same period.

MULCH - WASHED DAIRY WASTE (WDW)

DEFINITION

The application of manure which has been washed from milking parlors and pens.

PURPOSE

To protect soil from erosion and increase water holding capacity of soil for vegetative growth.

APPLICABILITY

On any slopes subject to wind or water erosion and areas which have been seeded.

PLANNING CRITERIA

- Washed manure is screened to remove most of the liquid, resulting in an odorless product that does not attract flies.
- Washed dairy waste is applied using a hydroseeder. Application rates of 2,500 pounds per acre in a water slurry (3,000 gallons per acre) are recommended.
- WDW is not a commercially available product.

EFFECTIVENESS

WDW is nearly effective as wood fiber (BMP I-11) in preventing erosion and as a mulch for vegetation. It can be cheaply produced and applied.

I-10

MULCH BLANKET

DEFINITION

The application of thin sheets of cellulose fibers bonded to a water soluble binder and meshed with a plastic or cotton net.

PURPOSE

To reduce erosion and provide mulch for vegetation.

APPLICABILITY

Used on bare slopes subject to erosion and on seeded areas. Mulch blankets are unrolled and stapled over seeded soil.

PLANNING CRITERIA

Blanket mesh openings are 1/4 inch by 1/4 inch and rolls have width of 75 inches and length of 500 yards. When blankets are saturated by runoff, the water soluble binder dissolves and the fibers loosen to form a mulch cover.

- Blankets may be applied across or down a slope.
- Sufficient overlap should be provided between rolls to allow for shrinkage.
- Stapling should be placed according to manufacturer's instructions.
- At the top of the slope runoff must be prevented from flowing beneath the blanket.
- Blankets should be placed loosely and contact the soil surface continuously.
- When unrolling blankets across slopes, the uphill overlaps the downhill blanket.

EFFECTIVENESS

Because mulch blankets require moisture for mulch to be released, mulch effectiveness will depend on available moisture. The mesh net does not provide direct control of erosion as does jute matting.

I-11

HYDROMULCHING

DEFINITION

The application of wood fiber mulch and tacking agent in a slurry with water.

PURPOSE

To uniformly and economically apply a temporary stabilization material (wood fiber) and water to a bare slope or other bare area. Hydromulch may be combined with hydroseeding as a revegetation method (BMP II-7).

APPLICABILITY

Can be applied to areas which are within approximately 200 feet of a road or other area which can be reached by truck. Small roadside slopes and large relatively flat areas are well adapted to this method.

PLANNING CRITERIA

Hydromulching can be combined with seed and fertilizer as a revegetation method (BMP Chapter II). The mulch will remain up to two years, but loses much of its effectiveness after the first year. Revegetation is needed to provide continued stabilization.

Hydromulching should be used only on physically stable slopes (natural angle of repose or less).

METHODS AND MATERIALS

- The hydromulching machine should be equipped with a geardriven pump and a paddle agitator. Agitation by recirculation from the pump should not be allowed. Agitation should be sufficient to produce a homogeneous slurry of tacking agent, mulch and seed fertilizer if used.
- Water should be applied at a minimum rate of 3,000 gallons per acre.
- Tacking agent should be applied at 200 gallons of wet ingredients per acre or 80 pounds of dry ingredients per acre.
- Wood fiber mulch should be included at a rate of 3,000 pounds per acre.
- When seeding is combined with hydroseeding, fertilizer of the specified formulation should be included at the specified rate.

- Specified seed mixtures should be included. No seed should be added to the slurry until immediately prior to beginning the seeding operation.

- Legume seeds should be pellet innoculated with the appropriate bacteria. Innoculation rates should be four times that required for dry seeding.

- The time allowed between placement of seed in the hydromulcher and the emptying of the hydromulcher tank should not exceed thirty minutes.

- Wood fiber may be dyed to aid in uniform placement. Dye should not stain concrete or painted surfaces nor injure plant or animal life when applied at the manufacturer's recommended rate.

- Application of the slurry should proceed until a uniform cover is achieved.

- The applicator should not be directed at one location for a period of time which will cause applied water to create erosion.

MAINTENANCE

Hydromulched slopes should be inspected periodically for damage due to wind, water or human disturbance. Damaged areas should be repaired immediately using hydromulching at the original specifications or straw mulch, BMP I-7.

EFFECTIVENESS

Hydromulching is an effective method of increasing water retention and thereby reducing erosion for up to six months to one year. Beyond one year the effectiveness drops off. Initial and short-term effectiveness for sediment generation from the slope compared to the bare slope. Within two years, the breakdown of wood fiber will have reduced the effectiveness 40-60 percent. Beyond that time only 10-30 percent effectiveness can be expected, and the mulch should be replaced. Nutrient generation reduction effectiveness is estimated to be 50-70 percent for six months, 20-50 percent up to two years, and 0-10 percent beyond two years.

I-12

PLASTIC NETTING

DEFINITION

A monolithic plastic clothlike material.

PURPOSE

To stabilize straw mulches on revegetation sites.

APPLICABILITY

On all sites where straw mulch cannot be punched into the soil. Jute matting is preferred.

PLANNING CRITERIA

Plastic nets are used similarly to jute nets or excelsior matting, but it has no mulch capabilities itself. Plastic nets are best used to hold down mulches until vegetation is established. It provides no soil stabilization or erosion control by itself.

Plastic netting is more durable than is jute or excelsior. It also is much easier to handle and requires less manpower than either jute or excelsior.

METHODS AND MATERIALS

- Plastic netting with mesh opening from 1/8 inch by 1/8 inch to 1/4 inch by 1/4 inch should be applied over straw mulch similarly to the method specified for jute netting in BMP I-5. Staples used to anchor the netting should be equivalent to those specified in BMP I-5.

- Plastic netting does not function as a mulch as does jute matting since it does not absorb water. Plastic netting anchors straw mulch in place.

- Straw mulch rates should be increased 25 percent when plastic netting is used.

EFFECTIVENESS

Plastic netting increases the effectiveness of straw mulch, but does not provide direct control of erosion and sediment and nutrient generation. Jute matting is the preferred alternative.

CELLULAR CONCRETE BLOCK REVETMENT (GOBI BLOCKS)

DEFINITION

Concrete building blocks used for permanent soil stabilization to enhance seeding efforts.

PURPOSE

To hold soil in place for vegetative establishment.

APPLICABILITY

Concrete block revetment is expensive and should only be used where support is available at the slope toe to support the weight of the blocks (such as a curb or other concrete structure) and, where a high degree of soil stabilization is necessary for vegetative success. This method is generally applied in urban areas where vegetation is desired for aesthetic appeal.

PLANNING CRITERIA

Concrete blocks are placed end-to-end in parallel adjacent rows across a slope. They are placed by hand into the soil at a depth approximately one-half the height of the block. If different sizes are used, all blocks within a row should be of same size and depths may be altered to provide a flush surface. Blocks of alternate rows should be staggered to prevent slippage. Once the areas to be revegetated is completely covered, seed can be applied over the blocks. Vegetation will eventually completely cover the blocks as plants grow between cells in the blocks.

MAINTENANCE

Growth of vegetation should be inspected regularly until permanently established.

COMPACTION

DEFINITION

Reduction in soil volume achieved by rolling, tamping, or vibration.

PURPOSE

To increase the density of soil to improve strength, reduce amount of long term settlement, and provide resistance to erosion.

APPLICABILITY

Compaction is used to stabilize fill material placed around various structures and to improve soil in place as foundation support for roads, parking lots, buildings, etc.

PLANNING CRITERIA

Generally projects requiring specific soil densities will have such requirements set forth in the contract. The following requirements may apply to road embankments and small dams:

- Loose lifts of soil placed in 6 - 12" thicknesses.
- Optimum soil moisture content.
- Proper compaction equipment. Sheeps foot roller for clay soils and smooth roller for sandy soils.
- Because compaction tends to increase runoff volumes, drainage from compacted areas should be carefully planned to protect adjacent, uncompacted soils.

For temporary dikes, berms, and open areas, compaction can be accomplished with dozer tracking and heavy rubber tired vehicles.

MAINTENANCE

Compaction around structures - generally requires no maintenance. Recompaction is part of routine maintenance on unpaved roads or parking areas.

GABIONS

DEFINITION

Large, single- or multi-celled rectangular wire mesh boxes that are filled with rock and wired together to form a protective structure.

PURPOSE

Permanent slope or drainage stabilization and erosion control.

APPLICABILITY

Gabions can be used to mechanically stabilize oversteepened slopes as retaining walls, or for revetments, weirs, channel linings, culvert headwalls, and culvert outlet aprons. They are particularly useful where seepage is anticipated.

PLANNING CRITERIA

Gabions to be installed in streambanks should be designed and installed according to Rule #9.3 of the Stream Channel Alterations, Rules and Regulations and Minimum Standards, Idaho Department of Water Resources, 1978. (See Appendix III - Volume I of this handbook).

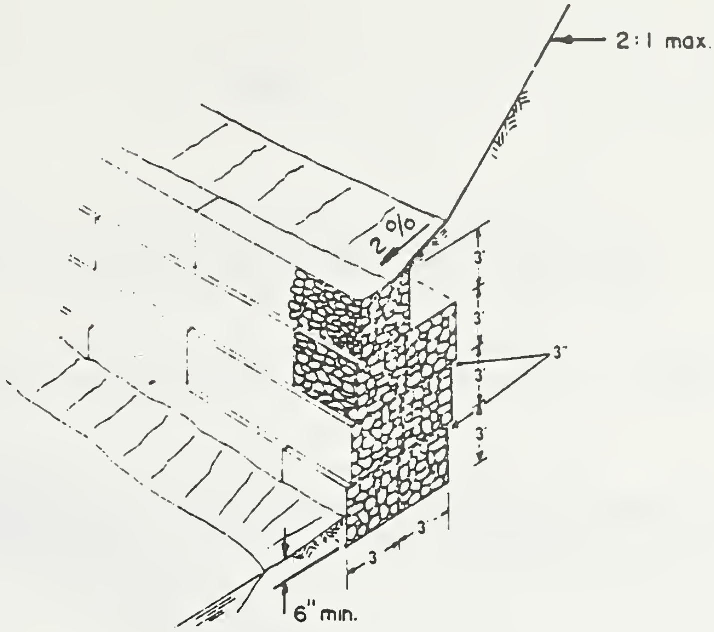
Gabions are rock-filled baskets which when wired together form flexible, permeable and monolithic building blocks that can be used for construction of erosion control structures. The wire baskets must be assembled and wired in position. The rock filling holds the gabions in place by gravity, but tie-backs may be used if conditions warrant additional structural strength.

METHODS AND MATERIALS

- Construction plans and specifications should be prepared by professionals familiar with the use of gabions.
- Site preparation requires rough grading of the site.
- Empty gabions are placed into position, wired together and filled with rock.
- Erosion and sediment control construction design should ensure that foundations are properly prepared to receive gabions, that the gabion structure is securely "keyed" into the foundation and abutment surfaces, and that rock used is durable and adequately sized to be retained in the baskets, approximately 4 to 8 inches in diameter.
- Typical sketches of two low gabion retaining walls are presented in Figure I-15-A. Other possible uses for gabions include slope revetment as shown in Figure I-15-B and channel stabilization.

MAINTENANCE

Periodic inspection is necessary for signs of undercutting or other instability. Damaged areas should be repaired immediately.



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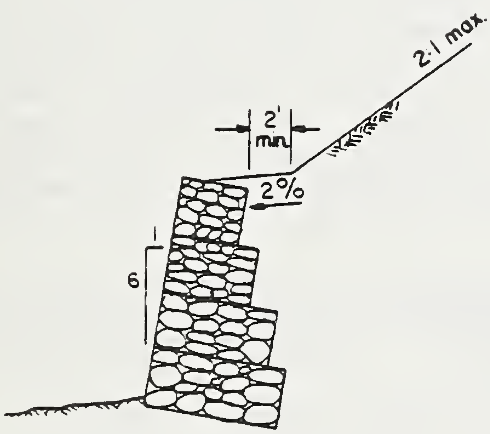
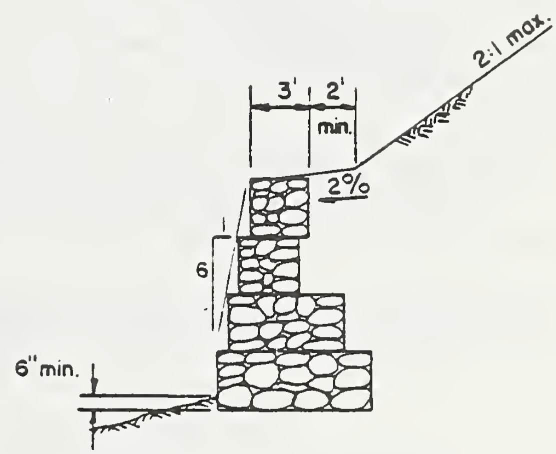
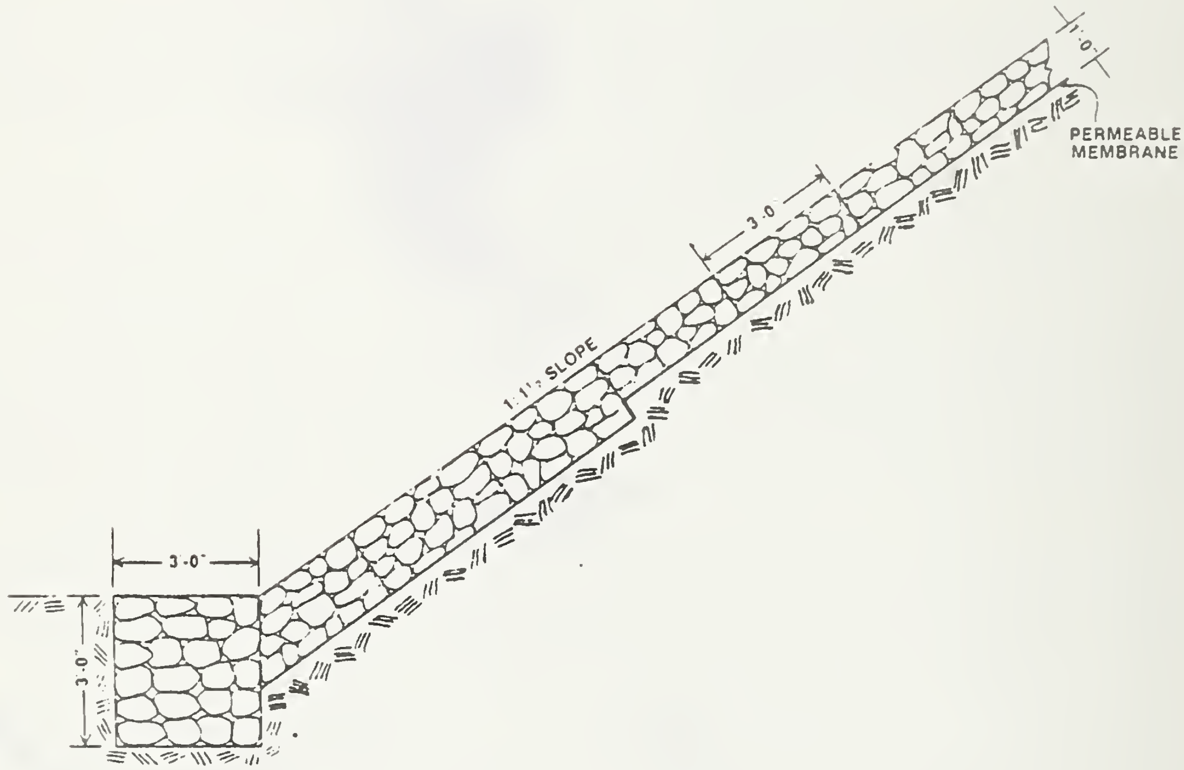




GABION RETAINING WALLS

Figure I-15-A



SECTION

no scale

GABION SLOPE REVETMENT

Figure I-15-B

RIPRAP

DEFINITION

A layer of loose rock or aggregate placed over the soil surface.

PURPOSE

To protect against erosion and dissipate energy of runoff or surface water flow.

APPLICABILITY

Used below drainage outlets and drop structures, along shorelines, and streambanks, and as a lining of erodible drainageways (ditches, channels, etc.). May be machine or hand placed.

PLANNING CRITERIA

Riprap to be installed along streamcourses should be designed and installed according to Rule #9.2 of the Stream Channel Alterations, Rules and Regulations and Minimum Standards, Idaho Department of Water Resources, 1978. (See Appendix III - Volume I of this handbook).

The minimum design discharge should be computed for channels and ditches based on peak discharge from a 10-year frequence rainfall event. A procedure is necessary for determining stone size which is stable under design flow conditions with a reasonable factor of safety. The design stone size used in this manual is the d_{50} or median stone diameter which is defined as the stone size where 50% of the mixture, by weight, is larger than that size. The riprap design procedure is given in Appendix D. Because the erosive forces of flowing water are greater in bends that in straight channels, a separate design procedure is included for these areas. If the riprap size computed for bends is within 10% greater than that for straight channels, then the straight channel size should be considered adequate to minimize the number of sizes required on a single project.

A layer of filter material should be placed between the riprap and underlying soil surface to prevent soil movement into and through the riprap where the following conditions exist:

1. Riprap is not well graded down to one-inch particles.
2. Riprap placed on channel side slopes is sand-size or finer with a plasticity index, PI, less than 10 and where soil lenses or layers are greater than three inches thick.

Two general forms of filter are available for this purpose. Either a single layer of plastic filter cloth, such as "Poly-Filter X" (Carthage Mills, Inc., Cincinnati, Ohio) or a layer of sand, gravel, or stone graded to sand size. Design criteria for an aggregate filter is as follows:

$$\frac{d_{15}\ \text{Riprap}}{d_{85}\ \text{Filter}} \leq 5 \qquad \frac{d_{15}\ \text{Filter}}{d_{85}\ \text{Base}} \leq 5$$

in which d_{15} and d_{85} are the respective sizes of the base, filter or riprap material where 15 and 85 percent, respectively, is finer: (The base is the soil layer beneath the filter.)

METHODS AND MATERIALS

The riprap should be composed of a well-graded mixture down to a one-inch particle size such that 50% of the mixture by weight is larger than the d_{50} size as determined from the design procedure. (A well graded mixture is composed primarily of larger stone sizes with a sufficient mixture of other sizes to fill voids between stones.) The following information applies to riprap and filter placement.

- Subgrade for riprap or filter should be prepared to required lines and grades. Fill required in subgrade should be compacted to a density approximately equal to surrounding undisturbed material.
- Riprap should consist of field stone or rough hewn quarry stone of a quality that will resist weathering and erosive force of water. Rubble concrete may be used provided it has a density of 150 pounds per cubic foot.
- Riprap should be placed to prevent damage to filter blankets. Hand placement may be necessary.
- Riprap larger than 12" should not be dumped directly onto plastic filter cloth since damage or displacement may result. Rather, a four inch minimum thickness of gravel should be placed over the filter cloth and prior to placing riprap layer. (Side slopes must be 2:1 or flatter to prevent slippage of gravel down filter cloth.)
- Minimum thickness of the riprap layer should be approximately 1.5 times the maximum stone size but not less than six inches.
- Riprap should extend up banks to a height equal to the maximum flow depth or to a point where vegetative protection can be established in channels.
- In channel with no riprap or bottom pavement, the toe of bank riprap should extend below the channel bottom a distance of 1.5 times the maximum stone size but not less than one foot unless a non-erodible hard rock bottom exists.
- Riprap placed in channel bends should extend upstream from the point of curvature and downstream from the point of tangency a distance equal to five times the channel bottom width (b); (length = 5b). The riprap should extend across the bottom and up both sides of the channel.
- Rock or gravel should conform to specified grading limits when installed as riprap or filter.
- Where filter cloth is used, overlaps should be minimum of one foot.

MAINTENANCE

Routine inspections should be conducted to detect damage or displacement of materials. Any filter cloth damage other than an occasional small hole should be repaired by placing another piece of cloth over the damaged part or replacing the entire cloth.

The possibility of damage by children should be considered in selecting riprap size, especially if there is nearby water to toss stones into.

I-17

NATIVE ROCK RETAINING WALL

DEFINITION

A low gravity wall constructed of rock materials native to the area in question.

PURPOSE

To provide an aesthetically attractive method for physically stabilizing a slope.

APPLICABILITY

The design described below should be used for low gravity walls up to about 5 feet in vertical height on slopes which are steeper than 2:1 and cannot be regraded to achieve this gradient.

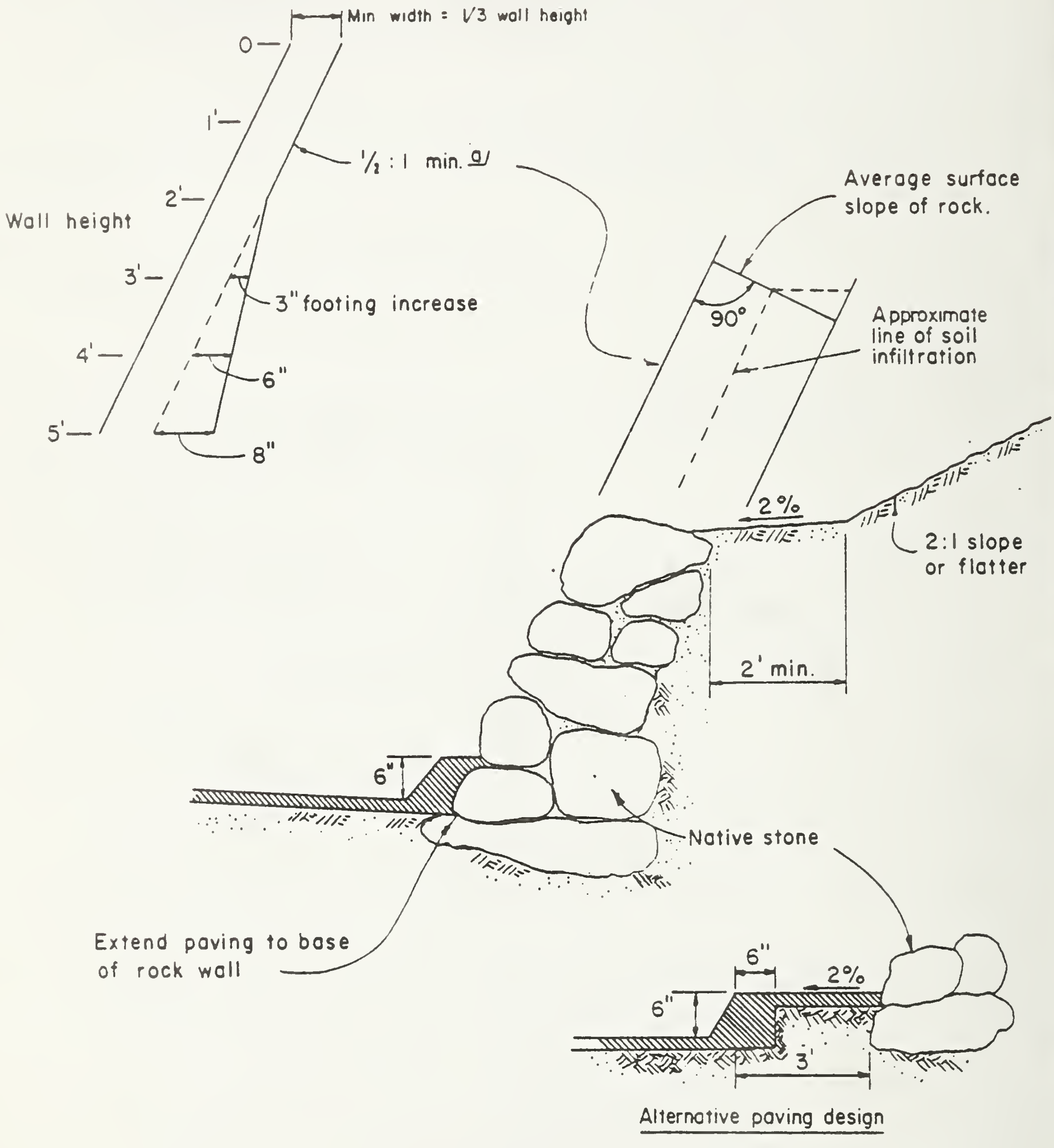
METHODS AND MATERIALS

- Remove all large rocks from the eroding slope face and stockpile on site.
- Excavate a footing trench along the toe of the slope (Figure I-17).
- Place the largest rocks in the footing trench with their longitudinal axis normal to the embankment face.
- Arrange subsequent rock layers so that each rock above the foundation course has a three-point bearing on the underlying rocks.
- The slope of the wall shall be between 1/2:1 and vertical, depending upon the height of the wall, the height of the slope, or the width of the right-of-way, or other limitations on space.
- Obtain fill material from the slope and place behind the rock wall. Slope above the wall should be maintained at 2:1 or less with a slope bench at the toe as specified in BMP IV-8. Backfill the footing trench with excavated material.
- If a roadway is located at the toe of the wall, pave the roadway up to the base of the rock wall and provide roadway curb for water transport (Figure I-17). If a roadway is not located at the toe of the retaining wall, slope the backfilled material away from the wall at 2 percent and stabilize it with procedures shown in BMP Chapter I and BMP Chapter II.

- Revegetate the stabilized slope immediately with a method applicable to the particular site (BMP Chapter II).
- The determination of final wall height, requirements for drainage, and acceptability of rock material must be made by on-site inspection.

MAINTENANCE

Inspect periodically for damage caused by subsurface drainage or material sloughing. Repair as needed.



a/ The wall may vary from vertical to an angle of 1/2:1

NATIVE ROCK RETAINING WALL
Figure I-17

I-18

REDWOOD RETAINING WALL

DEFINITION

A retaining wall constructed of redwood planking and posts.

PURPOSE

Mechanical stabilization of oversteepened or otherwise unstable slopes.

APPLICABILITY

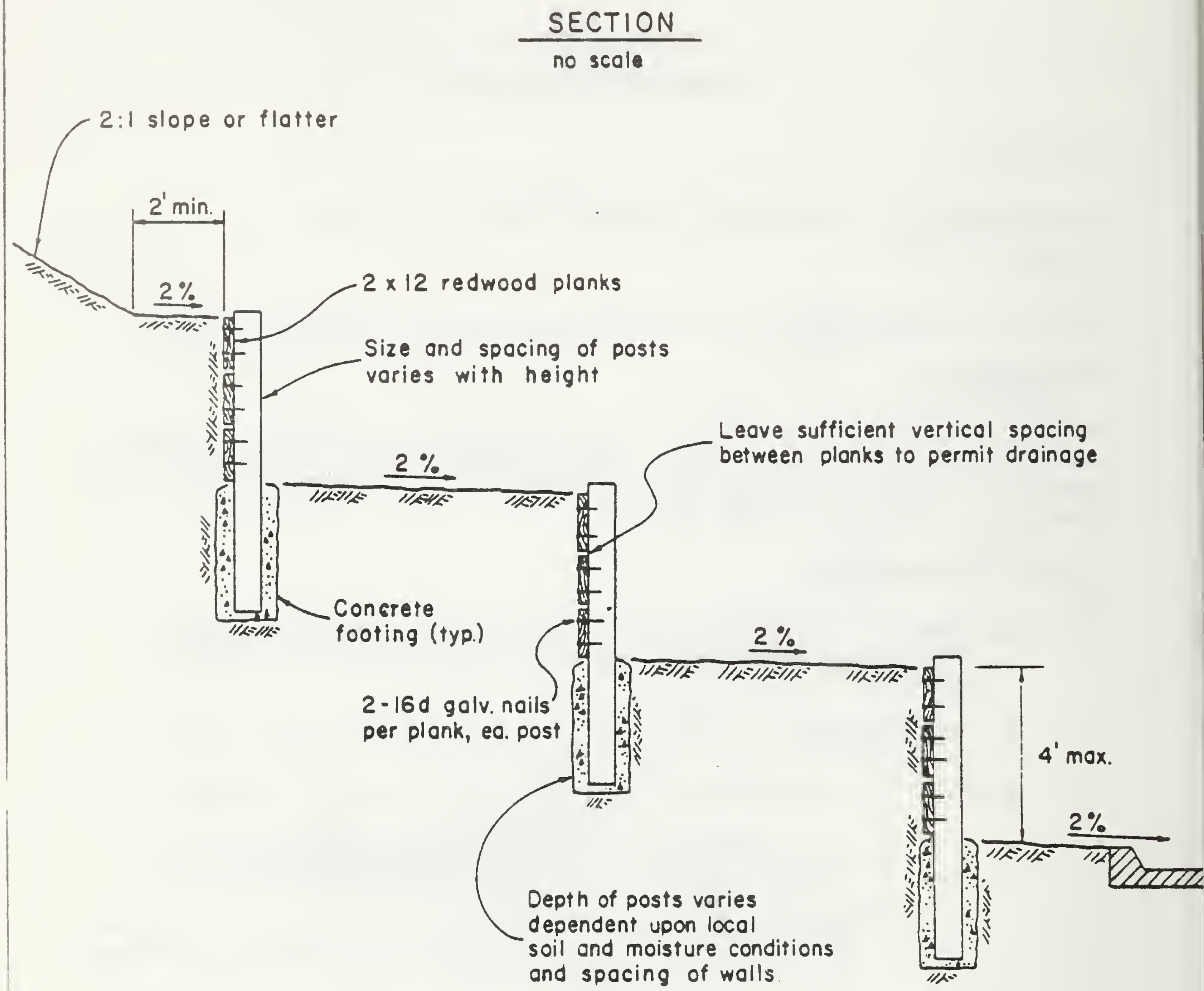
Redwood retaining walls are useful for relatively small slopes of loose material which are underlain by a rigid rock base material or a firm, nonplastic subsoil with high shear strength. The firm foundation is necessary to securely anchor the wall.

METHODS AND MATERIALS

- Plans and specifications should be prepared by professionals for most installations. A typical installation is presented in Figure I-18.
- Site preparation requires rough grading of the slope surface.
- Work from the bottom of the slope toward the top as follows:
    - Set bottom course of redwood posts into rigid base foundation material and secure with a concrete collar.
    - Install planking on the upslope side of posts. Provide sufficient vertical spacing to allow drainage at the base of the wall and between planks.
    - Backfill behind the wall with material from the slope above. Slope backfill material between redwood walls at 2 percent toward the top of the lower wall.
    - Proceed in a similar fashion up the slope to the desired height.
    - Revegetate backfilled benches behind the walls according to procedures applicable to the specific site (BMP Chapter II).

MAINTENANCE

Inspect periodically for damage. Repair as needed.



REDWOOD RETAINING WALL

Figure I-18

SODDING

DEFINITION

Establishment of perennial vegetation on critical areas.

PURPOSE

To provide immediate cover that will stabilize soil, control erosion and reduce runoff to downstream areas.

APPLICABILITY

Sod provides quick cover in protecting bared soils and stockpiled material, as a vegetative filter strip or as an energy dissipator at drainage outlets. It is most applicable where frequent runoff water is expected and cannot otherwise be controlled.

PLANNING CRITERIA

Site preparation and fertilizer application should be in accordance with BMP's II-4 and II-9.

Cultivated sod is preferred over native or pasture sod. Suggested varieties include Kentucky bluegrass, red fescue and red top. Sod strips of tall fescue and reed canary grass can be used to stablilize outlet and gully areas. Strips should be laid 2 to 6 feet apart at right angles to flow, depending on the site.

METHODS AND MATERIALS

Sod should be free of weeds and undesirable, coarse, weedy grasses. It should be of uniform thickness, approximately 3/4 inch plus or minus 1/4 inch at time of cutting (excludes top growth). The root mat should be compact to assure mechanical strength and assure early and firm anchoring to the soil. Only moist, fresh sod should be used. Harvest, delivery and installation should ideally occur within a period of 36 hours. The site should be graded as needed to permit use of equipment for soil preparation.

The following information applies to sod placement:

- Sod strips should be laid from the bottom up, on the contour, and never up and down the slope. Strips should be placed tightly together with ends staggered between strips to prevent voids which would cause roots to air dry.

- During seasonal high temperatures, lightly irrigate the underlying soil prior to laying sod.

- On gutter and channel sodding, the sod should be carefully placed in rows or strips at right angles to the centerline of the channel (flow direction).

- On steep graded channels, each strip of sod should be staked with at least two stakes not more than 18 inches apart. Wooden stakes should be 1/2 inch by 3/4 inch by 12 inches. They should be driven flush with the top of the sod and with the flat side against the slope.

- On slopes 3 to 1 or steeper where drainage into a sod gutter or channel is one-half acre or larger, 2 inch poultry netting or woven wire should be staked in place on the surface of the sod. The netting and sod should be staked with at least two stakes not more than 18 inches apart. The netting should be stapled on the side of each stake within 2 inches of the top of the stake. The stake should then be driven flush with the top of the sod and with flat side against slope.

- Sod should be tamped or rolled immediately following placement to eliminate irregularities and insure sold contact of the root and the soil surface below.

- Sod and the sod bed should be watered immediately to a depth of 4 inches and kept moist by watering for at least 30 days.

MAINTENANCE

Sodding requires no special maintenance once it becomes permanently established. Watering is necessary for approximately the first month. If it becomes evident that portions of sodded areas have not rooted, these areas should be replaced with sod of the same grass species as originally laid.

I-20

SPRIGGING

DEFINITION

A vegetative planting technique using rhizomes, stolons, shoots, or sprouts of a desirable species.

PURPOSE

To permanently stabilize slopes by holding soil in place.

APPLICABILITY

Sprigging may be performed on cut and fill slopes or other areas needing permanent soil stability. It is done to achieve more rapid growth of larger vegetation.

PLANNING CRITERIA

Sprigging may be accomplished by tearing sod apart and planting rhizomes or stolons. It may also be accomplished by transplanting shoots or sprouts. Sprigs are placed by broadcast (BMP II-5), punching-in or with a special sprig planter. Willow sprigs or other similar plants may be used with riprap or gabions where additional soil stabilization and vegetation is desirable.

MAINTENANCE

Early growth should be checked for damage or replacement needs until permanently established.

I-21

SUBSURFACE DRAINAGE
(SEEPAGE CONTROL)

DEFINITION

A system of drain tiles, pipes or tubing installed beneath the ground surface of slopes or other areas of groundwater seepage.

PURPOSE

To intercept subsurface water movement and to conduct intercepted water to a stable discharge. To prevent sloughing or failure of the slope due to surface springs or seeps.

APPLICABILITY

All cuts or other excavations which intercept groundwater such that water seepage and erosion occurs or danger of slope failure exists.

PLANNING CRITERIA

Two basic types of subsurface drainage systems exist: well point systems and trench systems. Well point systems are used on steep slopes and in areas which cannot be easily excavated. Trench systems are used on flatter slopes and slopes which can easily be excavated to install the system.

Well Point System

- Perforated pipe underdrains or horizontal drains should be installed in the overlying permeable soil layer just above the interface with the impermeable soil lens or rock layer.

- Perforated steel or other durable perforated pipe should be used. The upper end should be pointed and closed to allow it to be driven into the slope face. See Figure I-21.

- Minimum drain size should be equivalent to a 2-inch diameter pipe but 4-inch diameter is preferable.

- Depth, spacing, sizing and location of drains should be based on local site conditions including soils, groundwater, topography and outlets. A generally accepted procedure is to provide drain spacing equivalent to the depth of the overlying permeable soil material.

- Discharge from drainage pipes should be to a stable drainage conveyance system.

Trench System

- Trenches should be excavated to a minimum of 18 inches deep. The trench should be backfilled with 4 inches minimum of graded filter material, or it should be lined with filter cloth as provided below.

- Drains can include conduits of clay, concrete, metal, plastic or other materials of acceptable quality with strength and durability requirements appropriate for the site.

- Filter material of graded aggregate or filter cloth should completely enclose the pipe (see Figure I-21). A depth of not less than 3 inches is necessary under the drain if a sand-gravel filter is used.

- All drains should be laid to line and grade and covered with not less than 3 inches of approved hand-placed backfill and/or filter material (Figure I-21).

  - The upper end of all drain lines should be closed with concrete or other durable material.

  - If it is used, filter cloth should completely enclose the aggregate which surrounds the pipe as shown in Figure I-21

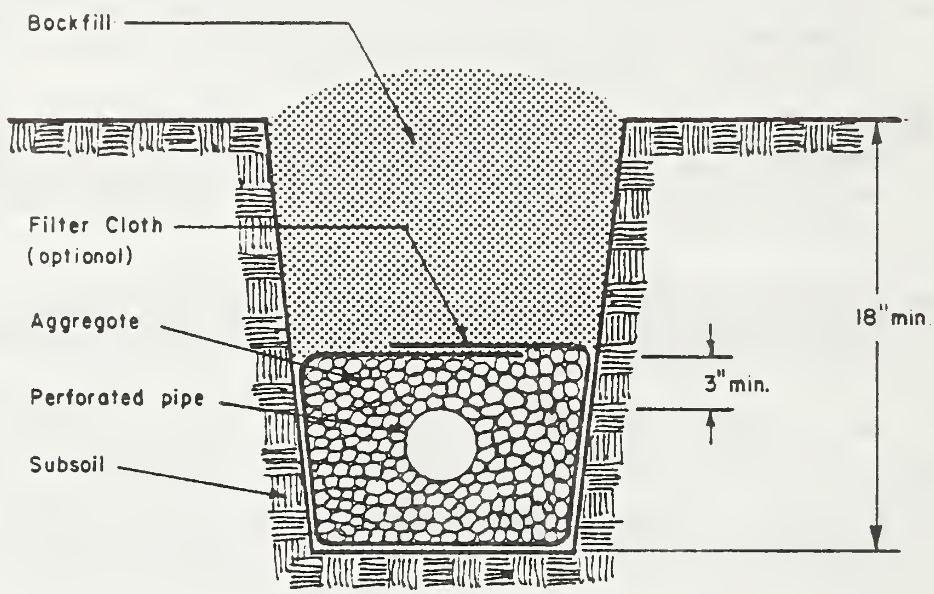
- Earth backfill material should be placed in the trench in such a manner that displacement of the drain will not occur, and so that the filter material, after backfilling, will meet the requirements of the design.

- The discharge from the drainage system should be to a drainage channel or stabilized system adequate for the quantity and quality of effluent to be disposed of.

- If the subsurface drains will receive vehicular traffic, the allowable loads on drain conduits should be based on the trench and bedding conditions specified for the job. A factor of safety of not less than 1.5 should be used in computing the maximum allowable depth of cover for a particular type of conduit.

MAINTENANCE

Drains should be inspected for clogging and slopes should be inspected for stability periodically. Repairs should be made as needed.



SECTION
no scale

SUBSURFACE DRAIN TRENCH SYSTEM

Figure I-21

TUBELINGS

DEFINITION

Containerized vegetation, usually forbs, shrubs, or trees, used for permanent revegetation.

PURPOSE

To stabilize soils and reduce erosion through vegetative establishment.

APPLICABILITY

Tubelings may be placed on any area to be revegetated, but are most useful on slopes or flat areas where arid, rocky or otherwise adverse topsoil conditions exist for supporting seed germination and early plant growth.

PLANNING CRITERIA

By planting partially grown plants, irrigation needs for seed germination are eliminated. Tubelings will act to reduce the slope length and modify expected soil loss (Appendix B). Spacing of tubelings on slopes can be calculated using Appendix C. Fertilizer may be applied as necessary (BMP II-9).

METHODS AND MATERIALS

Tubelings are commercially available and are often grown in long, narrow, reusable plastic sleeves. The length of the container will vary 6" to 24" depending on the desired root system depth. Root depth must be sufficient to extend below adverse surface conditions and attain a depth where adequate soil moisture is available. Choice of plant species should be compatible with native vegetation.

Planting of tubelings involves drilling holes to the depth necessary to accomodate roots. The tubeling container is inverted to remove the plant and tubelings are placed in holes by hand or with a special planter. (The University of Idaho is currently investigating mechanical planting methods under contract with USFS. To date, mechanized planting has been most successful on flat areas.)

MAINTENANCE

Growth should be checked periodically for replacement or supplemental fertilizer needs (see BMP II-10).

WATTLING

DEFINITION

Bundles of cuttings from growing willows, alders or similar plants used for slope stabilization.

PURPOSE

Stabilization of slopes and revegetation by producing favorable seed germination sites, reducing slope lengths for uninterrupted surface runoff, increasing water retention, and producing additional organic matter.

APPLICABILITY

Wattling is best applied to slopes which are no steeper than two horizontal to one vertical (2:1). Slope lengths which produce long, uninterrupted paths for surface runoff can be effectively reduced with rows of wattling. Wattling cannot be used as a substitute for retaining walls or similar devices to stabilize oversteepened slopes. Wattling is best applied to moist sites, but can be used on fairly dry sites.

PLANNING CRITERIA

Wattling can aid in achieving surface stability on a slope which is near its angle of repose, but which continues to erode due to surface runoff, frost heaving, needle ice, or other soil movement. Wattling bundles can vegetatively root and grow and continue to stabilize slope surfaces as revegetation planting. Rooting and growth occur when adequate water is available both at the time of placement and during the first few growing seasons.

Wattling acts to reduce slope length. Therefore, it modifies the factor (SL) in calculating expected soil loss (Appendix B). The maximum spacing (L) between lines of wattling bundles on a slope face can be calculated using Appendix C.

METHODS AND MATERIALS

Preparation of Bundles

- Wattling bundles should be prepared from living branches of shrubby material, preferably of species which will root, such as *Salix* spp. (Willow) and *Alnus* spp. (Alder).

- Wattling bundles may vary in length depending on materials available, but should be at least 5 feet long. Bundles should taper at the ends and should be 1 to 1-1/2 feet (maximum 2 feet) longer than

the average length of the individual branches to achieve this taper. Butts of individual branches should be no more than 1-1/2 inches in diameter.

- Alternate the direction of branches in each bundle so that approximately one-half of the butt ends lie at each end of the bundle.

- When compressed and tied, each bundle should be 6 to 10 inches in diameter.

- Bundles should be tied on not more than 16-inch centers with two wraps of binder twine or heavier tying material using a nonslip knot.

- Prepare bundles not more than two days prior to placement, unless they are kept covered and moist. In that case, they can be prepared up to seven days prior to placement.

Installation

- Existing gullies and rills should be filled and compacted prior to installation of wattling. Disturbance of the slope face and any existing vegetation should be minimized.

- Grade for wattling trenches should be staked with an Abney level or similar device and should follow slope contours.

- Determine trench spacing on large slopes using the formula for determining the maximum slope length Appendix C.

- Bundles should be placed in contour trenches dug 3 to 5 inches in depth and 6 to 10 inches across.

- Place stakes on 16-inch centers on the downhill lip of the trench.

    - Stakes should be live wattling material of greater than 1 inch diameter or 2 inch by 4 inch lumber. Live stakes are preferred. Lumber stakes may be used in compacted soils which prohibit effective use of live stakes. Stakes shall be 24 inches to 36 inches long. Steel reinforcing bar can be substituted only as specified below.

- Bundles should be placed in the trenches so that the ends of two bundles should overlap at least 1 foot. The overlap should be as long as necessary to permit staking as specified.

- Bundles of wattling should be staked through the center on approximately 30-inch centers. Place extra stakes on the downhill lip of the trench and through the bundles at each overlap of two bundles. Stakes can also be placed between rows of wattling to aid in revegetation.

- All stakes should be driven in to a firm hold, a minimum of 18 inches deep. Where soils are soft, longer stakes should be used. Where soils are so compacted that 24-inch wooden stakes cannot be driven in 18 inches, 24-inch sections of 3/8-inch to 1/2-inch diameter steel reinforcing bars may be used for staking.

- Work should proceed from the bottom of the slope to the top. Each row of wattling should be covered with soil and packed firmly on the uphill side by tamping or walking on the wattling as the work progresses up the hill. The downhill lip of the wattling may be left exposed when staking and covering are completed.

- Additional wattling should be placed as necessary for stability in seeps or other wet areas.

- A slope bottom bench should be placed below the slope as specified in BMP IV-8.

- The slope should be revegetated according to procedures in BMP Chapter II.

Performance of Work

The following procedure is recommended for work crew organization when placing wattling. Refer to Figure V-D-1.

- Have one crew gather wattling material and prepare it in bundles prior to moving to the site.

- For small jobs, all of the wattling can be prepared prior to commencing work on the job site.

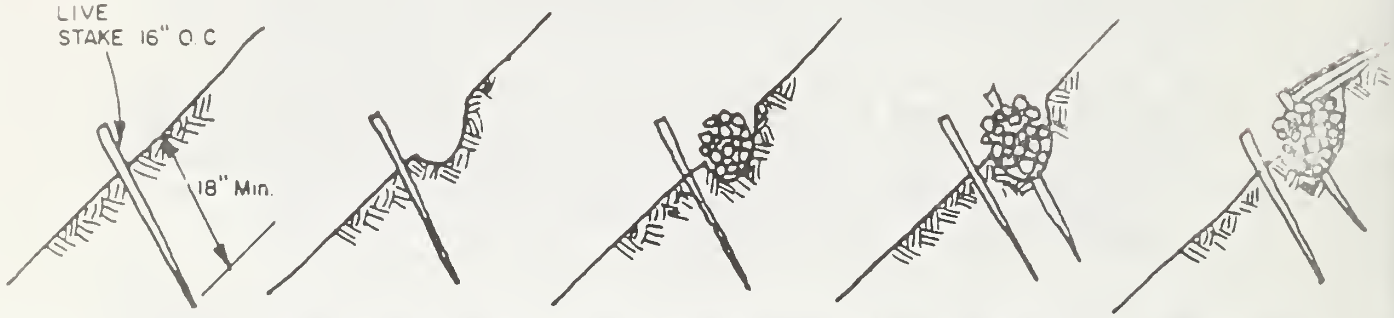
- For large jobs, prepare approximately half of the wattling bundles prior to commencing work on the job site. Keep a crew of three to to four persons making wattling bundles and transporting them to the job site while work proceeds.

- When work on the site begins, stake out the first trench lines with stakes on 16-inch centers using an Abney level or similar device.

- Dig the trench to a specified depth and width just above the line of stakes. Large rocks which are in the path of a trench should not be removed, but the trench should end at the rock and resume on the other side.

- Lay wattling bundles in the trench and stake them down, placing additional stakes through overlaps between bundles and stakes on the downhill side of all overlaps of bundles.

- When bundles are in place, stake out the next trench line while standing on the first line of wattling.
- The material excavated from the second trench should be cast on top of the first line of wattling. This material may be compacted by walking upon it while placing the bundles in the second trench and staking them. The greater the amount of traffic that the placed wattling recieves, the greater will be the number of rooting locations in the bundles.
- Try to avoid traffic on the rest of the slope as much as possible. Walk on the wattling lines.
- Work up the slope using the last placed line of wattling as a base from which to apply the next line.



STEP 1 STAKE ON CONTOUR

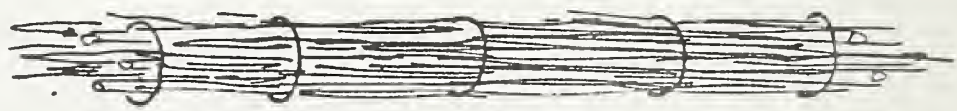
STEP 2 TRENCH ABOVE STAKE, 1/2 DIA. OF BUNDLES CAST SOIL FROM TRENCH DOWNHILL

STEP 3. PLACE BUNDLES IN TRENCH

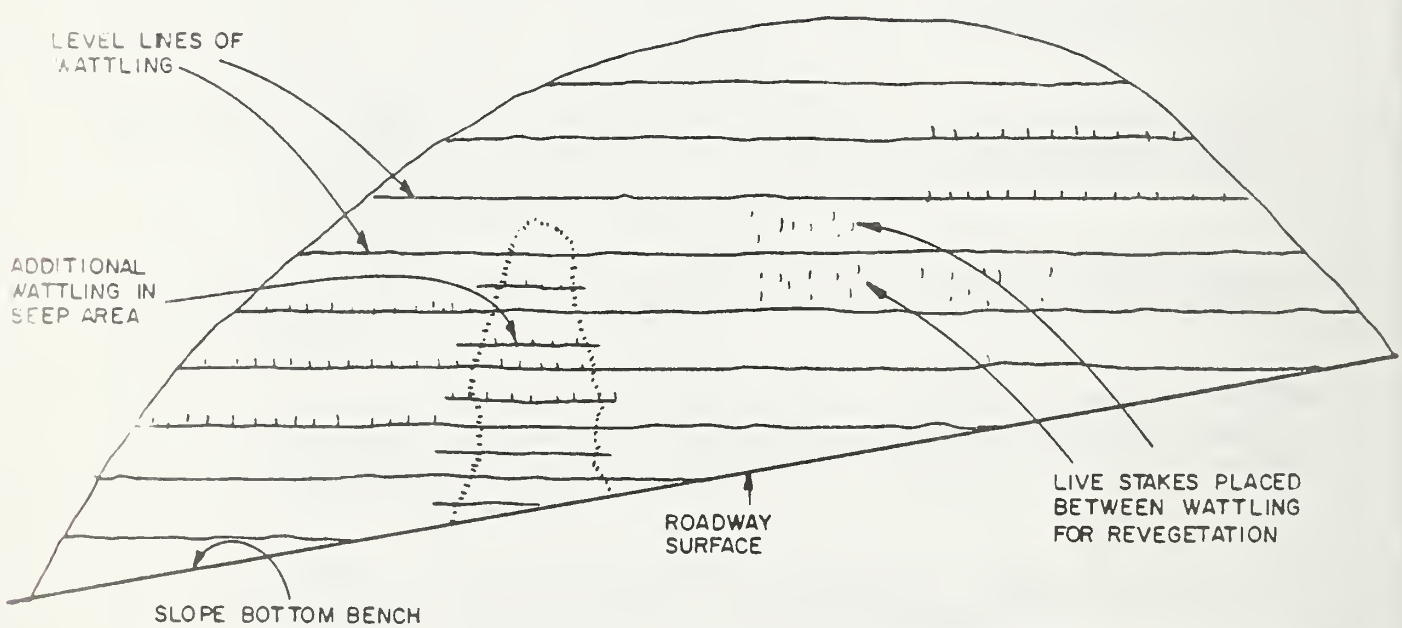
STEP 4. ADD STAKES THROUGH AND BELOW BUNDLES

STEP 5. COVER WATTLING WITH SOIL, TAMP FIRMLY

NOTE 1 WORK FROM BOTT TO TOP OF CUT OR FILL
2 WALK ON BUNDLES TO COMPACT OVERLAY SOIL
3. STAKES SHOULD BE LIVE WATTLING MATERIAL
4 SPACING OF ROWS SHALL BE DETERMINED BY BMP IV-B



PREPARE WATTLING: CIGAR-SHAPED BUNDLES OF LIVE BRUSH WITH BUTTS ALTERNATING, 8-10" DIA., TIED 12-15" O.C SPECIES WHICH ROOT ARE PREFERRED.



WATTLING INSTALLATION

Figure I-23

TIMING OF CONSTRUCTION AND CONTROL APPLICATION

DEFINITION

The timing of construction work and erosion control application to occur under optimal conditions.

PURPOSE

To minimize erosion and maximize effectiveness of control methods.

APPLICABILITY

Areas of work that may be planned for periods of low erosion potential. Areas where controls are to be installed as work progresses.

PLANNING CRITERIA

Construction work involving soil disturbance or exposure should be scheduled during seasonal low runoff periods under favorable soil moisture conditions.

Erosion controls should be installed in stages to protect completed work. Sediment collection systems should be installed prior to activities expected to produce sediment.

SURFACE AREA EXPOSURE

DEFINITION

Controlling the amount of area that is cleared and grubbed at any one time in preparation for construction.

PURPOSE

To reduce the amount of bare soil exposed to erosive forces.

APPLICABILITY

Areas where vegetation must be removed to facilitate construction.

PLANNING CRITERIA

The total surface area exposed at any one time should be kept to a minimum. The maximum exposure area should be specified in the construction plans prior to actual earthmoving.

JUNIPER REVETMENT FOR STREAMBANK STABILIZATION

DEFINITION

The placement of cut juniper trees anchored along streambanks.

PURPOSE

To stabilize erodible streambanks by reducing water velocity.

APPLICABILITY

In areas where juniper cuttings are readily available (southwest and eastern Idaho), bank stabilization may be accomplished with minimum equipment and cost. This method is a successful alternative to more costly stabilization structures and can be used on straight or slightly curved channel areas.

METHODS AND MATERIALS

Juniper limbs extending into the water reduce water velocities and thereby increase sediment deposition along the streambank. As silt builds up to form slopes, native plants may establish and provide additional soil cover and stability. The following information pertains to installation of juniper revetment.

Tree selections

- The tree species most often chosen for revetment is *Juniperus occidentalis*.
- The tree size selected will depend on the method of placement. Trees over 6" dbh are not recommended for hand placement.
- Green trees with bushy crowns are preferred over more slender ones because they can slow more water.

Placement

- Trees should be angled downstream with butts tied by #9 smooth wire attached to an anchor point. (See figure I-26). Fence posts or "dead manned" cable can be used for anchors.
- Posts should be driven to within 4" of the ground surface and at least 5' from the edge of the streambank. (Anchors driven too close to the edge can cause the bank to slough and trees to detach).
- If cable is used, it should lie flat on the ground to reduce hazards of tripping humans and grazing animals.
- Trees must be securely tied to cables to prevent water from cutting behind them.
- Where junipers are placed on the outside of curved areas, additional stabilization structures such as riprap, are needed to prevent water from cutting behind trees.

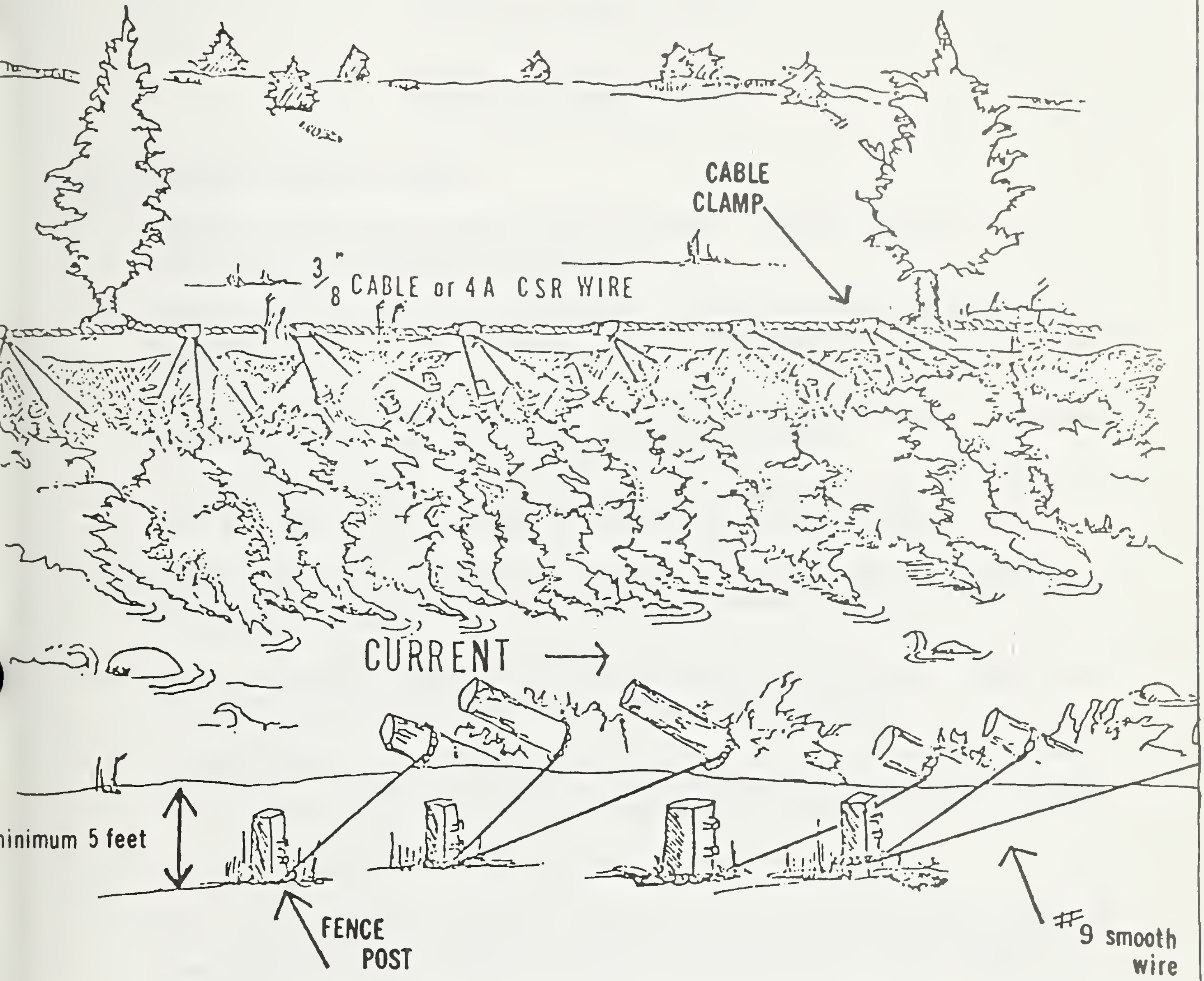
MAINTENANCE

Once established, juniper revetment generally requires no maintenance unless damaged by humans or grazing animals. Proper grazing management can reduce damage by livestock and allow encroachment of riparian vegetation on stream channels.

EFFECTIVENESS

Mean water velocities have been demonstrated to decrease 66 - 73 percent by this method according to a 1974-1979 study on the John Day River in Oregon.* The observed failure rate for revetment on the same study was only 4%.

* Sheeter G. R. and E. W. Claire, USDA Bureau of Land Management, May 1981. Use of Juniper Trees to Stabilize Eroding Streambanks on the South Fork John Day River. BLM Technical Note, Filing Code 6763.



JUNIPER REVETMENT FOR
STREAMBANK STABILIZATION

Figure I-26

CHAPTER II

VEGETATIVE STABILIZATION

Contents and Applicability

BEST MANAGEMENT PRACTICES (BMP):

II-1 GENERAL PLANTING AND SEEDING SPECIFICATIONS. General information applicable to revegetation projects.

II-2 SELECTION OF REVEGETATION TECHNIQUES. A guide to selection of appropriate methods for different conditions, and summary cost and effectiveness tables.

II-3 SELECTION OF SEED AND LIVE PLANTS. Specifications governing the species, quality and rates of application of seed and plants.

II-4 SEEDBED PREPARATION. Preparation of the soil surface prior to revegetation using seed to provide better plant growth conditions.

II-5 BROADCASTING SEED. Methods of scattering seed over the soil surface. Most useful on small sites, for repairing damage, or for very large, low angle rocky sites.

II-6 DRILLING SEED. Planting of seed with an agricultural drill. Useful on large, low angle sites with fairly loose, nonrocky soil.

II-7 HYDROSEEDING. The process of applying seed and fertilizer in a slurry with water. It may be combined with hydromulching. Applicable on steep or rocky sites close to vehicular access (<100 feet).

II-8 VEGETATIVE PLANTING. The method for planting living plants.

II-9 FERTILIZER. General specifications for use of fertilizers for commercial and residential use. Specific specifications for fertilizer use with revegetation methods using seed and with revegetation using vegetative plantings.

II-10 MAINTENANCE OF REVEGETATED AREAS. Protective measures, irrigation, fertilization and repair measures for all revegetated sites.

II-11 TOPSOILING. Placement of topsoil over a prepared subsoil for the purpose of enhancing revegetation conditions.

II-1

GENERAL PLANTING AND SEEDING SPECIFICATIONS

DEFINITION

The general rules which apply to all planting and seeding operations.

PURPOSE

To enhance the success of revegetation and to establish an understanding of the basic requirements of a successful revegetation program.

APPLICABILITY

All revegetation and landscaping work.

PLANNING CRITERIA

Seeding and planting information:

- Annual grasses and legumes are recommended for quick cover and rapid, temporary protection. Perennial grasses and legumes are for continued protection, as are wattling, shrub and tree plantings.
- All grass, legume, herb, shrub and tree stock used in revegetation projects should be of demonstrated viability and effectiveness in erosion control and soil stabilization projects.
- All legume seed should be innoculated with appropriate bacteria.
- Trees and shrubs should provide lasting vegetative stabilization and protection after the grasses and legumes decline.
- Shrubs and trees used in revegetation should match the vegetation existing on or near the site in species composition and density.
- Native shrubs, trees and herbs are recommended in order to maintain the biological integrity of the area being revegetated.
- Unless otherwise stated, shrub and tree plantings may be of stock grown either from cuttings or from seed.
- Bare root planting rates should be 25 percent higher than the rates specified in BMP II-3.

Site evaluation and modifications of revegetation methods:

- Existing soils survey reports should be consulted for each revegetation site or area. All major sites should be inspected and tested by a soil specialist for water holding capacity and nutrient levels.
- When soil pH is less than 5.5, that is, the soil is highly acid, seedling establishment may be retarded. To establish a more favorable soil pH, lime should be applied and incorporated into the top 4 inches of soil. The application rate should be 2 tons per acre unless otherwise specified by the soil specialist.
  - Lime may be powdered limestone or waste treatment lime. Waste lime from sewage treatment should be in dry powdered form with 15 percent or less organic matter.
- When frost heave potential is determined to be moderate or high, the following precautions should be taken:
  - Planting and seeding should be conducted from May 1 to August 1. Supplemental irrigation will be required for germination and establishment.
  - Mulch rates should be increased 50 percent over those specified in BMP Chapter I.
  - Areas damaged by frost heave should be repaired as specified in BMP II-10.
  - Follow-up applications of fertilizer should be made each spring for two years, according to BMP II-10.

Materials:

- Some seed requires pretreatment prior to planting. It is desireable to check with seed suppliers to ascertain the need and to acquire treated seed.
- Shrubs and trees may be seeded or planted from bare root or potted stock.
- Bare root shrub and tree seedlings should be kept bundled and in cold storage from time of receipt until planting.
- Potted shrub and tree seedlings should be stored in shade out-of-doors, and should periodically be lightly sprinkled with water to maintain soil moisture from time of receipt until planting, which should not exceed 30 days.

- When peat pots, paper pots, or plastic fiber containers are used, the pot may be planted with the seedling. Peat pots should be covered with soil or trimmed to the soil line to prevent the pot from wisking moisture from the roots of the seedling. Pots should not be buried more than 1/2 inch above the top of the pot. Depending on the planting method used, plastic fiber containers may be planted with up to 3 inches of the container above the surface as shown in BMP II-8.

- When metal containers are used, the container should be removed prior to planting. Careful removal of the pot will prevent damage to the root mass. The root mass and enclosed soil should be loosened gently by hand following removal from the pot. The plant should then be planted immediately.

Season of Seeding:

Selection of the improper season during which seeding work is permitted is a key item in insuring successful seedings on construction projects. Even if all other specifications are correct, if the timing of the seeding is incorrect, the seedlings are likely to fail. There is constant pressure to widen the seasons during which the seeding work is permitted. There is a "best" time, usually a period of three to four weeks, for sowing seed and it is wise to use this information when planning roadside seeding.

When seeding grass, normally fall seeding is more successful on "southern" sites and spring seeding is more successful on "northern" sites. Generally, the greatest risk of loss when seeding in the fall is that the planting may be done at a time when there is sufficient moisture for germination yet there is not sufficient time before freeze-up for plant establishment. In this case, the new seedlings are likely to be lost by winter dessication and frost heave. A minimum of 45 days growth is needed to assure that the seedlings will live through the winter.

When seeding in the spring the risk is that the planting may be done so late in the season that even though there may be sufficient moisture for germination, there is not sufficient time for plant establishment before the dry, hot weather arrives. If this occurs, the seedings are likely to be lost by summer drought. The same 45-day growth rule should be applied here.

Should roadside seedings on northern sites be planned for spring, some areas are too wet for construction work while others are too dry. As a result seeding is often not properly accomplished at the desired time. If seeding has been done in the fall, by springtime severe erosion often has destroyed much of the seeded area. There problems are difficult to overcome.

With the development of mechanically anchored mulch, use of fiberglass, benching, and the increased effort to maintain flatter slopes, better erosion control is possible. With the use of these procedures and materials, it is more feasible to plan fall seedings in all locations. Seeding in northern areas can be completed the following spring should it be impossible to finish the job in the fall as planned. In southern areas if the seeding is not finished in the fall as planned, completion should be delayed until the following fall, unless established water can be used. On dry-land seedings, Idaho can be satisfactorily divided into four seeding-season (Season of work) areas as follows:

Southern Idaho Type Sites

Fall Seeding

M.A.P.	SEASON
8" to 12"	Sept. 15 to Dec. 31
10" to 17"	Sept. 1 to Dec. 15

Northern Idaho Type Sites

Fall Seeding

15" to 22"	Sept. 1 to Dec. 15
20" +	Aug. 1 to Nov. 15

Note: The 20"+ zone, where chances of early fall moisture are good, provides two possibilities; seed as early as possible to take advantage of early seasonal moisture with time for establishment before freezing weather arrives or delay as long as possible and still have time to finish before bad weather begins. In this way, the risk of losing newly germinated seedlings by winter desiccation and frost heave can be largely avoided.

Spring Seeding

M.A.P.	SEASON

(Use primarily for completion of jobs already started)

15" to 22"	Feb. 15 to May 15
20" +	March 1 to May 30

When deciding in which site a planting area is located, the same precautions concerning use of the site guide outlined should be followed here. Usually the site determined for selecting the seed mix will be the same as for selecting the season of work. On sites to be seeded with establishment water, the dates for the beginning irrigation are as follows:

SOUTHERN IDAHO TYPE SITES

M.A.P.	Date to Begin Irrigation: Fall Season	Spring Season
8" to 12"	Aug. 15	May 1
10" to 17"	Aug. 7	May 10

NORTHERN IDAHO TYPE SITES

15" to 22"	Aug. 15	May 20
20" +	Aug. 7	May 30

(M.A.P. = Mean Annual Precipitation).

Irrigation:

- In determining the season of work, allow sufficient time for work just prior to the above dates for beginning irrigation. These dates will also serve as a guide for beginning application of establishment water as used on some dry land seedings.

- Irrigation should be supplied wherever possible. Soil should be wetted to field capacity to a depth of 3 to 4 inches at time of planting and each time the soil moisture drops below the permanent wilting percentage.

    - Irrigation water should not be applied at rates which result in erosion of the soil surface or damage to planted or seeded areas.

- When irrigating, care should be taken to insure a uniform moistening of the slope to prevent patchiness. Irrigation should cease before any area becomes saturated or wetted above field capacity.

- If portions of the slope vary in availability of water (springs, creeks, etc.), revegetation should be designed to place more water-tolerant species in the wetter areas and more drought-resistant species in drier areas.

- Irrigation should be continued during the first year after planting, as specified in BMP II-10. Irrigation should be reduced in the following year, and in the third and ensuing years. After the third year, irrigation should only be used to prevent failure of a revegetation project during extremely dry periods.

    - South-facing slopes should be seeded only in springtime or summer if irrigation is available to avoid frost heave and freezing of the seedlings. North-facing slopes may be seeded in fall.

    - Work should be scheduled to minimize the time of exposure of bare soil and partially completed work.

    - Weather forecasts should be consulted daily to prevent serious damage to a project. When storms are predicted during the revegetation process, work should be stabilized over the entire area, and a damage repair crew should be on the site during the storm.

Personnel:

- It is desirable for maintenance personnel who are inspecting revegetated sites to be equipped with straw, grass seed, fertilizer, and hand tools to allow on-the-spot repair of damaged areas.

- Revegetation labor forces should be under the direction of a person familiar with the technique being used.

- Proper instruction of the labor force is vital and may be obtained from the U.S. Soil Conservation Service, a University Extension agent, or professional nursery persons.

SELECTION OF REVEGETATION TECHNIQUES

DEFINITION

The procedure for selecting the proper revegetation method for a site.

PURPOSE

To relate the revegetation method to site conditions.

APPLICABILITY

On all revegetation projects.

PLANNING CRITERIA

Revegetation is a process that involves planting seeds and plants, fertilizing the soil, and providing soil stabilization until the vegetation develops an adequate root system and vegetative growth to stabilize the soil. The following tables should be used to determine which methods should be used to plant seeds and plants and provide soil stabilization on different types of sites.

Table II-2-A indicates the proper revegetation technique to use for specific site conditions. Table II-2-B specifies by number the Best Management Practice for temporary slope stabilization and revegetation method, the order in which the procedures are to be executed, and any specific information necessary to understand the method.

TABLE II-2-A

REVEGETATION AND SLOPE STABILIZATION METHOD SELECTION TABLE[1]

Slope Type	Gradient	Existing Vegetative Cover[2]	% Rock & Stone Exposed on Surface	Slope Face Length	Revegetation Method: Alternatives	Revegetation Method: Components
Cut or Fill	4:1 or flatter	None	<10-30%	<10'	A	Seed & mulch
				>10'	B,C,D	Seed & mulch or plantings
			>30%	NA[3]	A&D, B&D, C&D	Seed & mulch & plantings
		Partial	NA[3]	NA	D	Plantings
		Complete	NA	NA	None[4]	--
	4:1-2:1	None	<10%	<10'	A,C,F,G,D	Seed & mulch or plantings
			NA	10-20'	N,O,P	Seed & mulch & plantings
				>20'	H,I,J	Wattling; seed & mulch & plantings
		Partial	NA	NA	D	Plantings
		Complete	NA	NA	None[4]	--
	2:1-1.5:1[5]	None	NA	NA	K,L,M	Slope stabilization; seed & mulch & plantings
		Partial	NA	NA	K,L,M	Slope stabilization; seed & mulch & plantings
		Complete	NA	NA	None[4]	--
Abandoned Road	<4:1	None or Partial	<10%	NA	Q	Runoff control on slopes & drainage; seed & mulch & plantings
	<2:1	None or Partial	>10%	NA	R	Runoff control on slopes & drainage; seed & mulch & plantings
	>2:1	NA[3]	NA	NA	K,L,M[5]	Slope stabilization; seed & mulch & plantings
Unstable Drainage	All Conditions					
	<2:1	NA	NA	NA	None[4]	--
	>2:1	NA	NA	NA	BMP Chapter III & IV	

TABLE II-2-A
(continued)

REVEGETATION AND SLOPE STABILIZATION METHOD SELECTION TABLE[1]

Slope Type	Gradient	Existing Vegetative Cover[2]	% Rock & Stone Exposed on Surface	Slope Face Length	Revegetation Method: Alternatives	Revegetation Method: Components
Temporarily Inactive Construction Sites	All Conditions <2:1	None or Partial	NA	NA	S,T,U	Mulch
Active Construction Sites	All Conditions <2:1	None	NA	NA	S,T	Mulch

[1]Enter the table from left to right following the appropriate site conditions to select the proper revegetation method for the site.

[2]Areas of distinctly different existing vegetation coverage should be evaluated separately. the terms "none", "partial", and "complete" have the following meanings:

None = 0-20% coverage of the site
Partial = 20-50% coverage of the site
Complete = >50% coverage of the site

[3]NA means that the condition does not affect the selection of a revegetation method.

[4]Method E is required where drainageways are eroding or threatening to destabilize established vegetation.

[5]These methods require mechanical stabilization as shown in BMP Chapter VI and should be used where access or other considerations prevent regrading existing slopes according to the standard for slope design. These methods should not be used on new construction as they are not substitutes for proper design and construction.

TABLE II-2-B

DESCRIPTION OF REVEGETATION METHODS

NOTE: Designations indicate the specific Best Management Practice to use, IN THE EXACT SEQUENCE IN WHICH THE WORK IS TO BE PERFORMED, except that the fertilizer which is to be used is always specified last.

For example: Alternative A, as does every alternative, suggests the use of seed and live plant type quality and quantity (II-3). It then specifies that seedbed preparation be accomplished by hand (I-7), followed by hand broadcasting of seed (II-5). Straw mulch should be punched by hand (I-7) on the slope, maintenance procedures are suggested (II-10) and finally the fertilizer required by the seeding is specified (II-9).

STEP-BY-STEP DESCRIPTION OF REVEGETATION METHODS

Alternative	Operation in Order of Performance	Best Management Practice
A Small slopes with gradients as steep as 2:1	Grass, legume, shrub, & tree seed selection	II-3
	Seedbed preparation, by hand	II-4
	Broadcasting seed, hand labor	II-5
	Straw mulch, hand punching	I-7
	Maintenance	II-10
	Fertilizer	II-9
B Small slopes with gradients as steep as 4:1	Grass, legume, shrub, & tree seed selection	II-3
	Seedbed preparation by machine	II-4
	Drilling seed	II-6
	Straw mulch by machine	I-7
	Maintenance	II-10
	Fertilizer	II-9
C Small slopes with gradients as steep as 2:1	Grass, legume, shrub, & tree seed selection	II-3
	Seedbed preparation, some hand labor	II-4
	Hydromulching	I-11
	Hydroseeding, combined with hydromulching	II-7
	Maintenance	II-10
	Fertilizer	II-9

TABLE II-2-B
(continued)

STEP-BY-STEP DESCRIPTION OF REVEGETATION METHODS

Alternative	Operation in Order of Performance	Best Management Practice
D Slopes with gradients as steep as 2:1	Vegetative plant selection	II-3
	Planting	II-8
	Maintenance	II-10
	Fertilizer	II-9
E Unstable drainageways as steep as 2:1	Grass & legume seed selection	II-3
	Seedbed preparation, some hand labor	II-4
	Broadcasting seed by machine	II-5
	Straw mulch, machine punching	I-7
	Matting in drainageways	IV-6
	Maintenance	II-10
	Fertilizer	II-9
F Small slopes as steep as 2:1	Grass, legume, shrub & tree seed selection	II-3
	Seedbed preparation, some hand labor	II-4
	Hydroseeding	II-7
	Fiberglass roving	I-2
	Maintenance	II-10
	Fertilizer	II-9
G Small slopes as steep as 2:1	Grass, legume, shrub & tree seed selection	II-3
	Seedbed preparation, some hand labor	II-4
	Broadcasting seed by machine	II-5
	Straw mulching by machine	I-7
	Jute matting	I-5
	Maintenance	II-10
	Fertilizer	II-9
H Large slopes as steep as 2:1	Grass & legume seed; shrub & tree plant selection	II-3
	Seedbed preparation, some hand labor	II-4
	Wattling	I-24
	Hydromulch	I-11
	Hydroseeding, combined with hydromulching	II-7
	Vegetative planting	II-8
	Maintenance	II-10
	Fertilizer	II-9

TABLE II-2-B
(continued)

STEP-BY-STEP DESCRIPTION OF REVEGETATION METHODS

Alternative	Operation in Order of Performance	Best Management Practices
I Large slopes as steep as 2:1	Grass & legume seed; shrub & tree plant selection	II-3
	Seedbed preparation, some hand labor	II-4
	Wattling	I-24
	Hydroseeding	II-7
	Fiberglass roving	I-2
	Vegetative planting	II-8
	Maintenance	II-10
	Fertilizer	II-9
J Large slopes as steep as 2:1	Grass & legume seed; shrub & tree plant selection	II-3
	Seedbed preparation, some hand labor	II-4
	Wattling	I-24
	Hydroseeding	II-7
	Straw mulch	I-7
	Jute matting	I-5
	Vegetative planting	II-8
	Maintenance	II-10
	Fertilizer	II-9
K Slopes needing mechanical stabilization	Slope stabilization, as needed BMP Chapter I	
	Grass & legume seed; shrub & tree plant selection	II-3
	Seedbed preparation, moderate hand labor	II-4
	Hydromulch	I-11
	Hydroseeding, combined with hydromulching	II-7
	Vegetative planting	II-8
	Maintenance	II-10
	Fertilizer	II-9
L Slopes needing mechanical stabilization	Slope stabilization, as needed, BMP Chapter I	
	Grass & legume seed; shrub & tree plant selection	II-3
	Seedbed preparation, moderate hand labor	II-4
	Hydroseeding	II-7
	Fiberglass roving	I-2
	Vegetative planting	II-8
	Maintenance	II-10
	Fertilizer	II-9

TABLE II-2-B
(continued)

STEP-BY-STEP DESCRIPTION OF REVEGETATION METHODS

Alternative	Operation in Order of Performance	Best Management Practices
M Slopes needing mechanical stabilization	Slope stabilization, as needed BMP Chapter I	
	Grass & legume seed; shrub & tree plant selection	II-3
	Seedbed preparation, moderate hand labor	II-4
	Broadcasting seed, by hand	II-5
	Straw mulch, machine method	I-7
	Jute matting	I-5
	Vegetative planting	II-8
	Maintenance	II-10
	Fertilizer	II-9
N Slopes to 20' long, as steep as 2:1	Grass & legume seed; shrub & tree plant selection	II-3
	Seedbed preparation, moderate hand labor	II-4
	Hydroseeding	II-7
	Straw mulch	I-11
	Jute matting	I-5
	Vegetative planting	II-8
	Maintenance	II-10
	Fertilizer	II-9
O Slopes to 20' long, as steep as 2:1	Grass & legume seed; shrub & tree plant selection	II-3
	Seedbed preparation, moderate hand labor	II-4
	Hydroseeding	II-7
	Straw mulch	I-7
	Jute matting	I-5
	Vegetative planting	II-8
	Maintenance	II-10
	Fertilizer	II-9
P Slopes to 20' long, as steep as 2:1	Grass & legume seed; shrub & tree plant selection	II-3
	Seedbed preparation, moderate hand labor	II-4
	Broadcasting seed	II-5
	Fiberglass roving	I-2
	Vegetative planting	II-8
	Maintenance	II-10
	Fertilizer	II-9

TABLE II-2-B
(continued)

STEP-BY-STEP DESCRIPTION OF REVEGETATION METHODS

Alternative	Operation in Order of Performance	Best Management Practices
Q Abandoned roads as steep as 4:1 and with <10% rock & stone on surface	Grass & legume seed; shrub & tree plant selection	II-3
	Seedbed preparation on compacted road surfaces	II-4
	Drilling seed	II-6
	Straw mulch	I-7
	Vegetative planting	II-8
	Maintenance	II-10
	Fertilizer	II-9
R Abandoned roads as steep as 2:1 or >10% rock & stone on surface	Grass & legume seed; shrub & tree plant selection	II-3
	Seedbed preparation on compacted road surfaces	II-4
	Hydromulch	I-11
	Hydroseeding, combined with hydromulching	II-7
	Vegetative planting	II-8
	Maintenance	II-10
	Fertilizer	II-9
S Temporarily inactive or active construction site	Wood chip application	I-8
T Temporarily inactive or active construction site	Gravel mulch	I-6
U Temporarily inactive construction site	Chemicals & tackifiers	I-1

SELECTION OF SEED AND LIVE PLANTS

DEFINITION

Specification of type, quality and quantity of seeds and plants to be used for revegetation.

PURPOSE

To relate the revegetation species to the site conditions and to ensure the quality of applied seeds and plants.

APPLICABILITY

All revegetation efforts should conform to these procedures except where landscaping of a more specific design is desired and will provide adequate stabilization.

PLANNING CRITERIA

Seeds and plants should be adapted to the site conditions and should display the desired characteristics to achieve maximum success in revegetation and erosion control.

Before any revegetation work begins, the seed and vegetative stock necessary to accomplish the work should be selected, ordered and received. The type and amount of seed or vegetative stock must be determined at least one year, preferably two years, prior to the actual work. This time is required for seed and plant suppliers to acquire the necessary stock in the amount and quality desired.

Differences in weather conditions from year to year may make it difficult for seed suppliers to reliably meet contracts for seed. All revegetation project directors should be aware that the longer the period of time between a notice of intent to purchase amounts of seeds and the need to begin the seeding operations, the better will be the probability of receiving adequate supplies of the required seed. Contact with suppliers at an early date will help to avoid delays and misunderstandings at later times and will probably help to hold down costs.

The following procedures specify the type and amount of seed and live planting materials to be used on various sites.

These specifications require a careful site analysis. They are flexible, and when a specified mixture of seed or plant materials does not provide an approximation of the vegetation found nearby, the mixture should be appropriately modified to provide a more natural appearing result. Pretreatment of seed often is required. Consult a seed supplier or Agriculture Handbook #450, Seeds of Woody Plants in the United States, Forest Service, U.S. Department of Agriculture, for the recommended procedure.

Site Conditions

Local conditions of exposure, proximity to cuts, fills, drainage structures or other disturbances or development may modify either dry or wet sites. Care should be given to the identification of a site as either dry or wet. Familiarity with the site will insure against improper classification. Inspections during various seasons will be necessary in order to make a proper determination.

Each seeding project will usually come under one of the following sites:

Southern Idaho Type: 8" to 12" and 10" to 17" M.A.P. (Mean Annual Precipitation)

Northern Idaho Type: 15" to 22" and 20" + M.A.P.

Note that each standard mix (listed on the following pages) includes three grasses, one legume, and natives. Whenever natives are not desired in the mix, the "primary" grass in each mix should be increased by two (2) lbs. per acre. These mixes have been recommended by the Idaho Transportation Department and are available upon request to all state and county agencies.

The terms "Southern" and "Northern" are for identification of site only, indicating that the bulk of the seeding in Southern Idaho, for example, will come under these two sites; however, there are some Northern Idaho sites located in the south and there are some Southern Idaho sites located in the north. This shows that the guide must be used with some judgement, particularly where the M.A.P. of a project might require reconsideration as to which mix to use or whether to combine the mixes. There are definite reasons for using three (3) grasses, one (1) legume and possibly natives on each seeding project and this system should be used in nearly all cases. (See BMP II-10 for explanation).

The first thing the designer should do is determine if the project falls well within a site. If it does, and there are no special problems such as alkali, blowsand, or excessive groundwater, make the determination as to whether to include natives and go ahead. If it falls between sites or special problems are present, an agronomist should be consulted.

Seed Mixtures

Seeding with grasses and legumes provides rapidly growing plants with top growth that protects the soil surface from raindrops and root growth which provides surface soil stabilization. This quickly established cover will yield to native shrubs and trees as seeds from these plants arrive and are deposited in favorable microsites.

Purity and Germination Standards

"Minimum pure seed" refers to the lowest percentage of viable seed of the desired species which is allowable in the seed lot. "Minimum germination" refers to the lowest allowable percentage of the seed which will break dormancy and begin to grow. These specifications provide a method of ensuring that appropriate collection and cleaning methods are used by the seed supplier.

Reliable germination standards and seed purity standards do not exist for many herb, shrub, and tree seeds. The best guide for obtaining high quality seed is to deal with established, reputable seed dealers and to rely upon their experience and judgement. When seed purity and germination standards do not apply, performance standards will aid the contractor of a seeding job in meeting both the contract specification and seeding job in meeting both the contract specification and seeding performance expectations.

Live Plant Mixtures

When plants are grown from seeds in uncontrolled environments, the majority of the seeds do not normally germinate or the seedlings do not become established and grow into mature plants. When the seeds do grow and become established, a period of one to several years may elapse prior to the plant providing soil stabilization through root growth and canopy cover. Vegetatively planted plants which have been grown under controlled environmental conditions can greatly accelerate the process of vegetation establishment and soil stabilization.

Many species of native plants can be purchased for revegetation. The cost of the plants varies with differences in the amount of effort necessary to propagate the plant, the age of the plant, and the type and size of the container that the plant is in. Older individuals in larger containers generally survive more readily than younger plants from smaller containers, but the cost of the older plants is generally prohibitive for revegetation.

Plants sold without a container and soil around the roots are called "bare root" stock, and are much more economical than container stock when they are available. Bare root stock usually does not survive as well as container stock, and planting rates must be increased to provide adequate numbers of surviving individuals after planting.

Plant Quality

Plants to be used in vegetative plantings should be vigorous, healthy plants. Potted stock, whether in peat, paper, plastic net, plastic or metal pots should be "hardened off" in the intended planting area prior to outplanting. Bare root stock should be kept in cold storage in bundles until outplanted.

SEEDING GUIDE

SOUTHERN IDAHO TYPE SITES

Mix #1 - 8" - 12" M.A.P. (Mean Annual Precipitation)

GRASSES	LBS. BULK SEED PER ACRE
"Sodar" Streambank W.G. (AGRI)	9
Siberian W.G. (AGSI)	3
"Fairway" Crested (AGCR)	2
LEGUME	
Madrid Clover (MEOF)	1
NATIVES	
To be determined	3
Total	18

Mix #2 - 10" - 17" M.A.P.

GRASSES	
"Sodar" Streambank W.G. (AGRI)	9
"Topar" Pubescent W.G. (AGTR2)	6
"Fairway" Crested (AGCR)	2
LEGUME	
Ladak Alfalfa (MESAL)	1
NATIVES	
To be determined	3
Total	21

NOTE: Symbols for identification taken from U.S.F.S. "Intermountain Range Plant Symbols" - 1977.

SEEDING GUIDE

NORTHERN IDAHO TYPE SITES

Mix #1 - 15" - 22" M.A.P. (Mean Annual Precipitation)

GRASSES	LBS. BULK SEED PER ACRE
"Durar" Hard Fescue (FEOVD)	7
"Tegmar" Dwarf Intermediate W.G. (AGINI)	6
"Manchar" Smooth Brome (BRIN)	3
LEGUME	
Ladak Alfalfa (MESAL)	1
NATIVES	
To be determined	3
Total	20

Mix #2 - 20"+ M.A.P.

GRASSES	
"Durar" Hard Fescue (FEOVD)	7
Meadow Foxtail (ALPR)	4
"Manchar" Smooth Brome (BRIN)	3
LEGUME	
White Dutch Clover (TRRE)	1
NATIVES	
To be determined	3
Total	18

II-3-B

NATIVE SEED LIST

SOUTHERN

Seed Size*	Seed
S	Lewis Flax (LILE)
S	Palmer Penstemon (PEPA)
S	Globe Mallow (SPMU)
M	Galsam Root (BASA)
M	Lupine (LUPIN)
VS	Basin Big Sage (ARTRT)
L	Curleaf Mtn. Mahogany (CELEL)
L	Fourwing Saltbrush (ATCA)
L	Shadscale (ATCO)
S	Rabbitbrush (CHRY3)
L	Hackberry (CEOC)
L	Antelope Bitterbrush (PUTR)
S	Western Virginbower (CLLIL)
M	Black Locust (ROPS)
L	Ponderosa Pine (PIPO)
VL	Russian Olive (ELAN)
M	Siberian Pea Tree (CAAR)

* S - Small

M - Medium

L - Large

VS - Very Small

VL - Very Large

II-3-B

NATIVE SEED LIST

NORTHERN

Seed Size	Seed
S	Penstemon (PENST)
S	Bear-grass (XETE)
M	Aster (ASTER)
S	Mtn. Thermopsis (THMO)
M	Dogwood (CORNU)
S	Snowbrush (CEVE)
S	Snowberry (SYMPH)
L	Chokecherry (PRVIM)
M	Service Berry (CAMALA)
L	True Mahogany (CEMON)
M	Wood Rose (ROWOU)
S	Blueberry Elder (SAMBU)
S	Lodgepole Pine (PICO)
M	Grand Fir (ABGR)
L	Rocky Mtn. Maple (ACGLG)
L	Douglas Fir (PSMEM)
M	Mtn. Ash (SOSCS)

II-3-C

SPECIAL USE GRASSES AND LEGUMES

ALKALI TOLERANT

"Alkar" Tall Wheatgrass (AGEL3)

Alkali Saccaton (SPAIA)

"Lemmons" Alkali-grass (PULE)

SAND STILLING

Sand Dropseed (SPCR)

"Volga" Mammoth Wild Rye (ELGI)

Indian Ricegrass (ORHYH)

Other

Bulbous Bluegrass (POBU)

"Whitmar" Beardless W.G. (AGSPI)

"Alta" Tall Fescue (FEAR3)

"Reubens" Canada bluegrass (POCO)

"Fortress" Red Fescue (FERUR)

Seeding rates on these special use species to be determined according to conditions on each project where they may be needed.

NOTE: Symbols for identification taken from "Intermountain Range Plant Symbols" - 1977.

SEEDBED PREPARATION

DEFINITION

Preparing the soil for planting prior to revegetation.

PURPOSE

To provide the best possible environment for the establishment of plants.

APPLICABILITY

All sites which are to be revegetated using seeding techniques.

PLANNING CRITERIA

Seed germination and seedling establishment are enhanced by loosening the surface layers of soil prior to planting. This process can involve either hand or machine raking of the surface. Best vegetative results are obtained when seed is covered after sowing. After seeding, the area should be reraked to only a depth of 1/4-inch to 1/2-inch following the sowing of seed.

Seedbed preparation includes weed control and soil tillage needed for successful sowing of seed. Good seedbed preparation is probably the hardest to achieve of any phase of seeding operations but it also may be the most important. For purposes of discussion, seeding areas may be separated into five types:

A. Rocky (untillable).

B. Benched (serrated).

C. Very steep (steeper than 2:1).

D. Steep (steeper than 3:1 to 2:1).

E. Sloping (3:1 or flatter).

In most cases rocky slopes of any gradient need not be disturbed if there are sufficient cracks for the seed to fall into. The only thing that could be done would be to walk a cleated crawler tractor up and down the slope or something similar to open or create crevices. Motorized sheet foot packers have been used on flatter areas.

Preparation of seeding areas:

- <u>Areas to be seeded</u> should be maintained reasonably free of weeds by mechanical means or application of appropriate chemicals until seeding time. Weeds should be kept from going to seed.

- <u>Areas to be seeded by drilling</u> should be cultivated to a minimum depth of 3 inches. The soil should be worked to obtain a surface that will permit proper operation of seeding equipment.

- On areas to be seeded by broadcasting, the seed bed should be tilled immediately prior to seeding to a roughened condition and the soil made loose to an approximate 2-inch depth. Soil condition similar to that obtained by walking a cleated crawler tractor up and down the slopes is required. Where slopes are benched no additional preparation will be required.

- Benched or serrated slopes need no preparation as sloughing of soil from the bench above will tend to cover seed.

- Seeding very steep slopes is an extremely difficult problem. However, if seeding is called for on the plans and the slopes are not benched, a reasonably good seedbed may be provided by working a cleated crawler tractor up and down the slopes by use of a winch or another tractor stationed at the top. Cross-slope dragging with a cleated cat track will do a satisfactory job in the looser soils.

- Steep slopes can be cat-walked up and down in most soils. Cat-walking leaves a good seedbed by firming the loose soil and loosening the hard soil and should be completed immediately ahead of broadcasting the seed on both cut and fill slopes on both very steep and steep slopes.

- Sloping areas can be prepared with conventional equipment, such as: disc, bull tongs, or rippers, and patrol. Fill slopes 3:1 or flatter possibly will not need preparation; however, they should be checked for satisfactory condition of firmness and looseness. It cannot be assumed that they are satisfactory.

- On very steep and steep slopes, soil should be tilled to a 2" depth and on sloping areas to a 3" depth. On areas to be drilled, soil should be prepared to a condition in which a drill and possibly a crimper disc will function properly. On areas to be broadcast seeded, soil is prepared to provide coverage for the seed by sloughing of the soil and moisture holding by the cross-slope basins.

- Slopes to be topsoiled should be roughly finished. After topsoil has been spread, the surface should be prepared for seeding as specified above.

- On areas subject to severe erosion, the extent of seed bed preparation should not exceed the area on which the entire seeding and mulching can be applied within one day's operation. If conditions occur which prevent seeding in a proper furrow, or if the roughened condition is destroyed, the contractor should prepare the seed bed again.

Seedbed Preparation on Abandoned Roads:

- If the roadway is densely compacted, rework roadway with a subsoiler to a depth of 8 to 10 inches. Space ripping bars approximately 18 inches apart.

- Ripping should be along the slope contours. Each pass should be in the opposite direction from the preceding pass to avoid buildup of material at the roadway edges.

- Rock and boulders should remain in place to the maximum extent possible.

- Construct slope face interruptor (BMP - III-8) trenches to reduce uninterrupted slope length. Spacing should be determined by the method presented in Appendix C.

II-5

BROADCASTING SEED

DEFINITION

The process of uniformly casting seed and fertilizer on the soil by hand or with mechanical devices.

PURPOSE

To provide a uniform covering of the site with seed and fertilizer.

APPLICABILITY

To be used when revegetation specifications call for seeding grasses, shrubs, herbs, or tree species on slopes which are too steep or rocky for use of other seeding methods. Seeding is often unsuccessful on cut slopes which are too hard and smooth for seed coverage by soil sloughing or as fill slopes where soil is too loose to hold sufficient moisture for seed germination.

PLANNING CRITERIA

Seeding of grasses, legumes, shrubs, and trees may be accomplished at the same time, or any of these seed types may be sown separately. Broadcasting seed provides uniformly distributed seed on the soil surface. The soil must be raked to properly cover the seed and to enhance germination. Broadcasting seed is particularly adapted to use on steep or rocky sites, abandoned roadways, or sites with limited access or where hand labor is used.

For germination to occur, seeds should be just barely covered with soil for about a two week period when soil temperature is above 50°F. Survival following germination depends on having selected the proper season of seeding and the right seed mix.

- The following sequence is recommended for materials application:

    1) Fertilizer should be applied first and worked well into soil (see BMP II-13).

    2) Prepare seedbed as directed in BMP II-4. Soil condition similar to that obtained by walking a cleated crawler tractor up and down the slopes is required. This loosens up the soil on the cut slopes and compacts the soil on fill slopes, as well as leaving cross-slope basins for holding moisture in place.

    3) Apply seed by either wet or dry broadcast. Seed placed in a hydroseeder should be used within 30 minutes after the seed has been introduced in the water.

    4) Apply mulch. Soil conditions may warrant some delay before applying mulch since wind and rain will slough soil to cover seed.

- Grass seed, herb seed, shrub seed, tree seed and fertilizer may be mixed together in the specified proportions prior to broadcasting. If a mechanical broadcast device is used, however, all seeds and fertilizer grains must be approximately the same size. With different sized seeds several passes will be necessary, one pass for each size. Application rates for different passes must be adjusted.

- Rice hull dilution may be used to assure propoer rates of application of different sized seed and fertilizer. This process is explained in BMP II-6.

- Breast seeders or "belly grinders" and truck- or tractor-mounted automatic seeders are preferred for broadcast seeding where they can be used. A more uniform application results from the use of these devices than from hand broadcasting. Hand broadcasting works well for maintenance seeding and seeding small areas.

- Broadcasted seed should be lightly raked and covered with a shallow layer of soil between 1/4 and 1/2 inch thick. This soil cover protects the seed and helps germinating seeds take root. Raking should begin immediately following seeding, and requires only a garden type rake for small areas. Agricultural rakes or spring-toothed harrows set very lightly will work for large, flat, or gently sloping areas. Hand raking is required on steep slopes regardless of size of the area.

EFFECTIVENESS

Broadcasting seed provides an effective method of scattering seed uniformly. If the seed is properly covered with soil and appropriate mulches and irrigation are applied, germination and establishment are generally better from broadcasted seed than from seed sown by hydroseeding, but not as good as the germination and establishment from drilled seed due to the difficulty of properly covering all of the seed on any but the most ideal sites. However, broadcasting seed is approximately equivalent to hydroseeding in effectiveness.

DRILLING SEED

DEFINITION

Planting seed and fertilizer using an agricultural or wildland seed drill.

PURPOSE

To plant seed at a uniform depth in the soil.

APPLICABILITY

For use on relatively flat slopes which are not too rocky to prohibit the use of a tractor and drill.

PLANNING CRITERIA

Drilling of grass, herb, shrub, and tree seeds provides the maximum possibility of successful germination and growth with the minimum investment in labor, seed, and fertilizer. Mixture proportions can be accurately managed and a uniform planting at the correct rate can be achieved. Drilling should be conducted as quickly as possible upon completion of grading on a construction site.

Proper drilling technique is of major importance in obtaining successful seedings. Most failures attributable to drilling are the result of placing seed too deep or too shallow in the soil, or in a situation where moisture will not accumulate near the seed. Factors affecting this include: improper seedbed preparation, incorrect disk spring pressure, failure to use depth guages where needed, drill speed too fast, drilling when wind is too strong, or using the wrong kind of drill.

- The seedbed must be loose enough to allow drill disc penetration but not so loose that depth control is lost. Pressure of the springs on the discs allows considerable control over this; however, in some cases, depth guages are necessary as spring adjustment is too limited. Even if the drill is properly adjusted, if it is pulled at high rate of speed or if there is a high wind, the seed will be left on the surface.

- When mulch is not to be used, a double-disc drill is required. The drill is then adjusted and operated in such a manner that the seed is placed at the bottom of small, approximately 2" depth, cross-slope furrows with only a thin soil covering. The depth of soil covering the seed immediately after drilling should not exceed 1/2 inch. If the furrows are good and seed is <u>accurately</u> placed in the <u>bottom</u> of the furrow, almost no covering is needed as wind and water will help cover the seed by sloughing of the soil.

- When mulch is to be crimped into the soil, the cross-slope furrows should not be deep. They should be just deep enough to hold the seed in place, with a maximum soil coverage of 1/2", until the crimping is completed. The crimping action will tend to cover the seed even more.

- The goal is to place the seed just under the soil with provision for moisture holding. Both the furrows and the mulch serve to accumulate moisture. Once the drill is adjusted, watch the seed, wind conditions, and free-flowing of spouts. If the drill happens to not be equipped with an agitator and the seed bridges over, this can be corrected by use of baling wire properly attached in drill box. Look to see where seed is placed in the soil. The seeding rate should also be checked periodicall and adjusted as necessary.

- Should there be intermittent rocky areas included in the area to be drill seeded, the drill may be raised when going over these rocks. If the drill is such that the discs can be raised just enough to clear the rocks and the seed delivery system still remain in gear, this can serve as a broadcast method on these areas. If not, the seed should be broadcast later on the rocky areas by hand or some other broadcast method.

- Fertilizer of the specified formulation should be applied at the rate specified in BMP II-9.

  All seeds and fertilizer may be mixed prior to planting, unless extreme differences in size would prevent the proper operation of the drill. In the event seed sizes differ radically, separate passes should be made to plant different size groups, seed may be separated into alternate bins in the drill or dilution of the seed with rice hulls may be used to control seeding rates. Dilution of the seed mixture with rice hulls aids in simplifying drill calibration procedures, keeping seed mixtures in constant proportion, allowing uniform distribution of seed and preventing equipment clogging.

II-7

HYDROSEEDING

DEFINITION

Applying seed, fertilizer, tacking agent, and water as a slurry. The slurry is sprayed onto the site.

PURPOSE

To uniformly and economically apply seed, fertilizer, tacking agent and water to a bare slope or other bare area.

APPLICABILITY

Large (1/2 acre), reasonably stable bare slopes (natural angle of repose or less) or areas which are near roads or other areas which can be reached by truck. Smaller areas can be seeded as economically by other methods.

PLANNING CRITERIA

Hydroseeding involves placing seed, fertilizer, a tacking agent, and water with a small amount of dyed wood fiber into a tank and agitating the mixture into a uniform slurry. This slurry is sprayed upon the site.

Hydroseeding applies the seed directly to the soil surface. A mulch must then be applied on the surface and raked to cover the seed with soil. Hydroseeding and hydromulching can be used in two separate operations on the same site to provide the most effective application of seed and a mulch blanket, but the cost increases with a two-stage seeding and mulching operation.

Hydroseeding is usually combined with hydromulching (BMP I-11) to apply both seed and mulch to the site at one time. The mulch used is a wood fiber which has been dyed to aid in uniform application. The major shortcoming of combining the two procedures is that a significant proportion of the seed is suspended in the mulch blanket and does not come into contact with the soil. This reduces the effectiveness of the seeding method.

METHODS AND MATERIALS

- The hydroseeder should be equipped with a gear-driven pump and a paddle agitator. Agitation by recirculation from the pump is undesirable. Agitation should be sufficient to produce a homogenous slurry of seed, fertilizer and tacking agent in the designated proportions.

- Water should be applied at a rate of 3,000 gallons per acre.

- One hundred fifty (150) pounds per acre of wood fiber should be added to aid uniform application.

    - If hydroseeding is combined with hydromulching, utilize mulch specifications contained in BMP I-11.

- Tacking agent should be applied at 200 gallons of wet ingredients per acre or 80 pounds of dry ingredients per acre. If hydroseeding is combined with hydromulching, use specifications in BMP I-11.
- Fertilizer of the specified formulation should be included at the specified rate to avoid seed damage.
  - Some slow-release granular fertilizers may sink rapidly and cause plugging of the pump or hoses. Both the hydroseeder manufacturer and the fertilizer manufacturer should be consulted regarding the appropriateness of the fertilizer for hydroseeder applications.
  - If the fertilizer cannot be applied using the hydroseeder, broadcast using methods presented in BMP II-5.
- Seed mixtures should be included at the specified rate. No seed should be added to the slurry until immediately prior to beginning the seeding operation.
  - Legume seed should be pellet innoculated with the appropriate bacteria. Innoculation rates should be four times that required for dry seeding. Legume seed should be placed in the mixing tank after all other ingredients have been included, as pellet innoculated legumes may have the coating washed off in the mixing tank.
  - The time allowed between placement of seed in the hydroseeder and emptying of the hydroseeder tank should not exceed 30 minutes or seed damage is likely to occur.

EFFECTIVENESS

On ideal sites, hydroseeding is equally effective in uniformly scattering seed as is broadcasting seed, but is not as good as drilling seed. However, it is applicable to more different types of sites than is drilling seed, and on steeply sloping sites it can provide more uniform application rates than broadcasting.

II-8

VEGETATIVE PLANTING

DEFINITION

The process of establishing vegetation by setting out plants which have been grown to specified size or age.

PURPOSE

To establish shrub and tree species of high quality with sufficient density to provide slope stabilization and erosion control.

APPLICABILITY

- Any finished slope which will remain undisturbed for at least ten years.
- Streets and ski runs which have been abandoned permanently.
- On active ski runs using vegetative planting with low-growing shrubs.
- All types of landscaping.

PLANNING CRITERIA

Many shrubs and trees are difficult to establish from seed in natural environments and natural seed crops vary widely from year to year. Rapid invasion from native vegetation and rapid establishment of sown seed of woody species is therefore unreliable. Vegetative plantings are used to provide living shrubs and trees which will grow to adequate size to provide soil stabilization and erosion control faster than seeds of woody species can germinate and grow to these dimensions.

Extremely rocky slopes or areas which have significant quantities of natural vegetation are difficult to seed and mulch effectively. Vegetative plantings can be used in these situations to provide additional stabilization.

Vegetative plantings of native species provide long-term soil stabilization which is aesthetically harmonious with natural vegetation and which requires little long-term maintenance. Short-term maintenance is necessary to ensure the establishment of the vegetation.

- Vegetative planting may be combined with seeded grasses and legumes which provide immediate surface coverage.

- Vegetative plantings should be of species which are native to the area.

- Planted material may be grown from either cuttings or seed and may be potted (containerized) or bare root stock.

  - Store bundled bare root planting stock, whether tree or shrub species, in a cool, moist place from time of receipt until time of planting. This time should not exceed 10 days.

  - Store potted planting stock in shade, out-of-doors, and kept lightly sprinkled with water to maintain a moist soil from the time of receipt to the time of planting. This time should not exceed 30 days.

- Irrigation of vegetative plantings during the first two years following planting is required to increase the survival rate. The soil should be wetted to field capacity to a depth of 3 to 4 inches at the time of planting and each time the soil moisture level drops below the permanent wilting percentage.

- Voluntary or unskilled labor may be used in planting. However, a supervisor who is skilled in the techniques being used should direct the labor.

METHODS AND MATERIALS

The following procedure should be used:

- Basins 12 inches in diameter and depressed no more than 2 inches from the elevation of the downslope lip should be constructed (see Figure II-8-1).

- The plant should be placed near the downslope lip as shown in Figure II-8-1 This allows sloughing from the slope to fall into the basin without burying the young plant.

- Holes should be opened with a planting bar or shovel as shown in Figure II-8-2.

- Apply fertilizer at the rate specified (see BMP II-13).

- Plant the mixture of trees and shrubs which have been prescribed according to soil type in BMP II-3 In no case should less than 700 plants per acre be planted.

- Plants should be placed in the planting holes so that the crown of the plant is at the surface of the soil. No air space should be allowed around the roots, nor should the roots be folded under, as shown in Figure II-8-2.

- Tree species may be of bare root stock or of potted stock. Pots should be one-gallon size or larger.

- Shrub species may be of bare root stock or of potted stock. Pots should be as specified below.

  - The preferred planting pot is composed of a tube of woven plastic which is planted with the plant contained in it. The pot deteriorates over time (Conwed or equivalent). The pots should be 2 inches in diameter and 12 inches long, with both ends open. Use 9 inches of potting medium to grow the individual, with 3 inches of the tube rising above the potting mixture. The upper portion provides rodent protection when the stock is planted.

  - Paper pots must be 2 to 3 inches square and 9 to 12 inches long. The paper around the rim should be removed to ground level at planting.

  - Peat pots are not recommended since research has shown greater mortality of plantings in peat pots due to drying. If peat pots are used, any exposed peat pot material showing after planting whould be removed.

  - No container should be less than 2 inches wide and 6 inches deep.

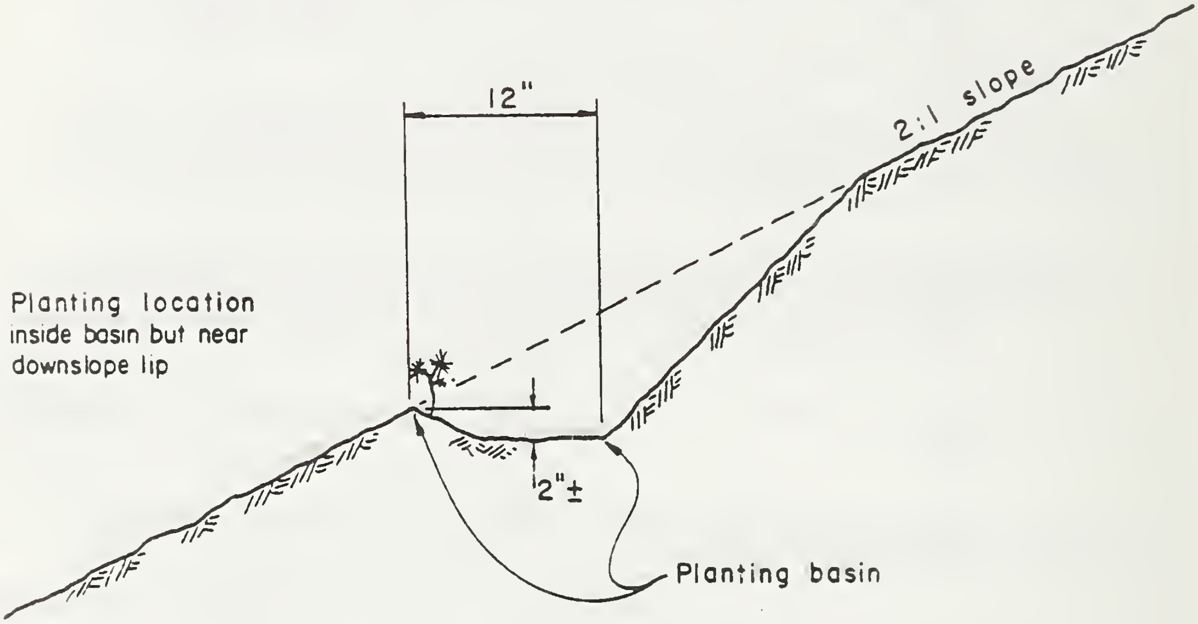
  - The growth medium should approximate the soil type on the revegetation site.

  - If bare root stocks are used, planting rates should be increased by 1.25 times the stated rate.

  - Wood chip or wood fiber mulch should be placed to a depth of 2 inches around each plant.

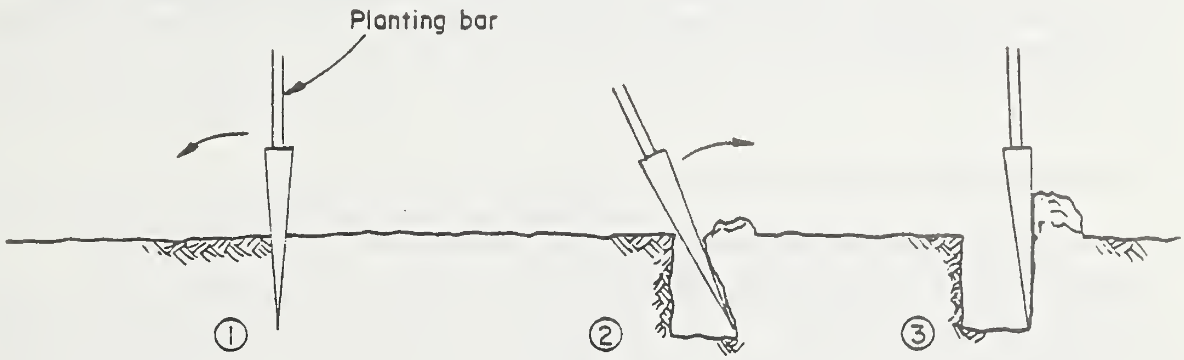
EFFECTIVENESS

Since vegetative planting places living plants on a site, thus decreasing the length of time necessary to establish a complete revegetation project, it is more effective than seeding methods for revegetation. Adequate maintenance is absolutely necessary to achieve this effectiveness since vegetative plantings require irrigation for at least the first year, and will benefit from irrigation for two or more years.

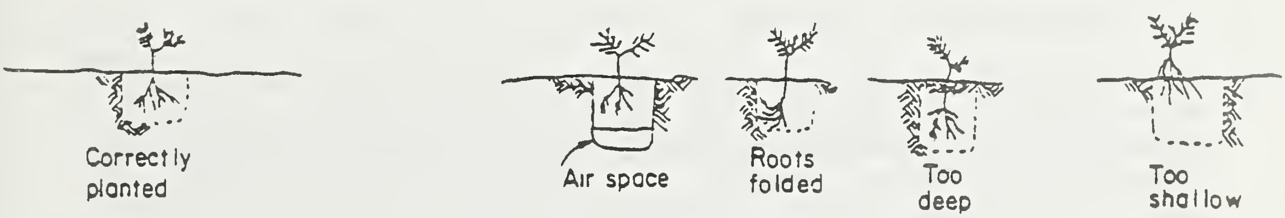


SECTION
no scale

PLANTING SCHEMATIC
Figure II-8- A



Preparation of planting hole using planting bar (Dibble)



Incorrectly planted

PLANTING METHOD

Figure II-8-B

II-9

FERTILIZER USE

DEFINITION

A guide to selection of fertilizer type and application rates.

PURPOSE

To prevent improper and excessive use of fertilizers and resultant water quality deterioration, while providing for the success of revegetation and landscaping efforts.

APPLICABILITY

- All revegetation efforts.

- Routine maintenance of revegetated or landscaping sites, including commercial and residential applications.

PLANNING CRITERIA

Fertilizer should only be used when soil nutrient deficiencies exist and establishment of desired vegetative growth is impaired. Application of fertilizer on disturbed area seeding is beneficial to new seedings if the proper kinds and quantities of fertilizer are specified. On the other hand, it can be detrimental if incorrectly specified. For example too much nitrogen (N) can destroy the seeding particularly in the dryer areas of the state. Failure to apply needed nutrients may result in poor establishment or complete failure of the seeding. For selection of fertilizer and recommended application rates, see Table II-9. The following information pertains to types of fertilizers.

General Applications

- Slow-release fertilizers utilize either bacterial action in the soil or osmosis to release nutrients. In the first group, the same factors which govern plant growth rates play a role in determining the rate at which nutrients become available, by affecting bacterial activity. The second group relies on the availability of water to produce an osmotic gradient to release nutrients. Slow-release fertilizers provide the most reliable method of providing plant nutrients, and are best adapted to application during seeding, vegetative planting and maintenance of established vegetation.

- If a fast-release fertilizer is needed, selected fertilizer should include forms of nitrogen, phosphorus, and sulfur. Phosphorus aids in root establishment and initial plant growth. Nitrogen maintains the growth of the plant. Sulfur could be included in the fertilizer as some soils may be deficient in this nutrient. The best fast-release fertilizer for this purpose is ammonium phosphate sulfate (16-20-0). Granite dust is an excellent source of potassium and for that reason potassium is not needed.

- Fast-release or conventional fertilizers release nutrients rapidly, making them available for immediate plant use. This form of fertilizer is therefore best adapted to maintenance operations. When conventional fertilizers are applied with seeding operations, nutrients can be leached out of the soil before the seeds germinate.

- Maintenance applications should be made when loss of vigor or color or slow growth indicates a nutrient deficiency. At least one maintenance application usually is required. This should be administered in the spring following the original planting.

- If fertilizer applications at the rates recommended below fail to result in healthy vegetation, do not apply more fertilizer to the site. Obtain a soil test from a qualified soil specialist to determine nutrient deficiencies. Follow the recommendations of the soil report in determining fertilizer type and application rates.

- Soil tests are recommended on all revegetation sites larger than one acre prior to any revegetation work commencing.

- Organic soil amendments, such as manure, sewage sludge, and composted organic waste, provide slow-release plant nutrition, act as mulches, and add organic matter to the soil. Their use is recommended in soils with low moisture holding capacity and in poorly developed soils such as subsoils exposed during construction.

- Nutrient concentrations in soil amendments vary widely and unpredictably and deficiencies can occur. They should be used with fertilizer at the rate specified.

Seeding Applications

When hydroseeding, broadcasting, or drilling methods are used to plant seed, the following criteria apply:

- Initial seeding operations for areas with reasonably flat slopes (3:1 or less):

    - Whenever topography allows, dry steer or cow manure should be applied at a rate of 10 tons per acre and incorporated into the top 4 inches of soil.

    - Apply slow-release fertilizer, formula 20-10-5.

- Initial seeding operations for areas with steeper slopes (3:1 or steeper):

    - Apply granular slow-release fertilizer (formula 20-10-5) and pelleted or granular conventional fertilizer (formula 16-20-0).

    - When used near surface water or areas of subsurface water which is close to the surface, only slow-release fertilizer should be used.

- Maintenance operations on all slopes:

  - When plant inspection or soil testing reveals nutrient deficiencies, pelleted or granular conventional fertilizer formula 16-20-0 should be applied.

  - One follow-up application of conventional fertilizer should be scheduled for the late spring following the initial application.

Planting Applications

When containerized plants are set out into planting basins as specified in BMP II-4 the following fertilizer application rates apply:

- One 5-gram pellet of slow-release fertilizer, formula 20-10-5, should be placed approximately 2 inches below the bottom of the root mass of all plants which are planted from peat pots, tarpaper pots, plastic fiber pots or other containers of less than 1/2 gallon capacity.

- One 21-gram pellet, two 10-gram pellets or four 5-gram pellets of slow-release fertilizer, formula 20-10-5, should be placed approximately 2 inches from the root mass of all plants from one-gallon size containers. Four 5-gram pellets are preferred.

- 21-gram pellets should be centered under the root mass.

- 10-gram and 5-gram tablets should be spaced around the perimeter of the root mass.

When bare root plants are planted into basins as specified in BMP II-4 the following fertilizer application rates apply:

- One 5-gram pellet of slow-release fertilizer should be placed at the bottom of the planting hole, approximately 2 inches of loose earthen material should be backfilled over the pellet, and the plant should be planted above the pellet.

- No fertilizer should be used with uprooted cuttings, as when willow or alder cuttings are used with wattling.

TABLE II-9

In the past, much effort has been expended on soil testing, with questionable results. The problems faced in getting representative samples where construction efforts strip the top soil, change the slopes and expose the parent material brought about efforts to find a better method of determining fertilizer needs. With this in mind, the following has been prepared with the assistance of the University of Idaho and the Soil Conservation Service. It is an empirical guide based on the best information available with regard to the inherent nutrient deficiencies of the parent materials which are largely exposed during construction efforts. The General Soil Map for Idaho is used as a reference with the recommended nutrient list concurring with the General Soil Legend. General Soil Map for Idaho should be obtained from your local Soil Conservation Service office.

After determining in which moisture zone the area to be fertilized is located, consider the additional factors that may be present that will affect moisture availability. Some factors are: 1) Other sources of water (ground moisture, establishment water, etc.), 2) Soil type (sand or clay, etc.), 3) organic matter level (high or low), 4) Aspect of the site (south or north facing, etc.).

Soil problems indicated by the pH (soil test) and/or indicator plants found in the area will require consideration as to whether soil amendments are needed.

LEGEND SYMBOL	pH RANGE	RECOMMENDED NUTRIENT
A	4.5 - 7.0	N - based on available moisture P - 35#/A S - 10-15#/A B - 1-2#/A
B	6.0 - 7.5	N - based on available moisture P - 35#/A K - 35#/A S - 10-15#/A
C_1-C_7	5.0 - 7.6	N - based on available moisture P - 35#/A K - 40#/A S - 10-15#/A Lime - 2-4 ton/A
C_8-C_{12}	6.5 - 8.5	N - based on available moisture P - 35#/A K - 35#/A S - 10-15#/A
D	6.5 - 8.0	N - based on available moisture P - 15#/A Salt - can have accumulation of excessive salts

II-10

MAINTENANCE OF REVEGETATED AREAS

DEFINITION

The process of irrigating, fertilizing and repairing revegetated areas.

PURPOSE

To insure the success of revegetation efforts and the establishment of vegetative cover.

APPLICABILITY

All slopes and areas which have been revegetated within the past one to five years.

PLANNING CRITERIA

The success of revegetation efforts is strongly dependent upon maintenance. In some years, little or no irrigation or repairs will be necessary, but during severely dry summers regular irrigation can make the difference between success and failure of entire revegetation projects. Damage caused by surface water runoff must be repaired immediately, as this damage is progressive and small rills can grow to gullies and rill systems which can destabilize the entire area and destroy the revegetation which has become established on the site.

Periodic fertilization of grasses and legumes during the first few years following seeding helps these plants to maintain vigorous growth and develop extensive root systems which help to stabilize the soil surface.

<u>Irrigation</u>

- Irrigation should be planned at the outset. An irrigation schedule should be included in the revegetation element of the Construction Plan.

- Conduct watering as frequently as necessary during the growing season to prevent the moisture content from dropping below the permanent wilting percentage for the soil.

- Keep soils moist from planting time until sprouting. The germinated seed should not be permitted to dry out.

- Coordinate watering with weather predictions to prevent over-watering and erosion damage.
- Continue irrigation until the end of the growing season or the onset of cold weather.
- Watering may be by tank or pumper truck equipped with a fine spray nozzle, or by portable pipe sprinkling systems equipped with "rainbird" type sprinkler heads.
- Reduce irrigation frequencies during the second season. This practice allows plants to begin adapting to the natural water regime of the site, while providing adequate water for growth during the young growing stages.

Maintenance

- Maintenance personnel should be equipped with shovels, grass seed, rakes and straw to allow repair of small failures and damage wituout the necessity of sending out a repair crew.
- Maintenance personnel should inspect the site for inadequate plant establishment or physical damage periodically throughout the year.
- Revegetation and slope stabilization should be inspected monthly during the period April 15-October 15 and periodically during the period October 15-April 15, and irrigated and/or repaired as required.
- Revegetation facilities should be inspected during major storm or snowmelt events.
- Erosion on slopes, in drainages, on revegetation sites, or other locations should be prevented through prompt repair of any failure, incipient gullies, rills or other erosion. If massive failure is evident, the area should be reestablished and new improvements should be designed and installed to prevent surface water quality degradation.
- Care should be taken to prevent all foot and vehicular traffic across the revegetated area.
    - A barricade equivalent to that shown in Figure II-10 should be constructed where required to prevent unauthorized vehicular traffic. Signs shall be posted to inform the public of the need to keep off the area.

- Vehicle closures may be used where access requirements dictate the need to enter, but where general use should be prohibited.

- Fences, cordons, and other pedestrian training devices should be used where appropriate to prevent pedestrian traffic on revegetation projects.

- Berms, rocks, slope interruptor trenches, curbs, bars and similar barriers should be used where appropriate to prevent vehicular traffic on revegetation projects.

- 200 pounds per acre of 16-20-0 fertilizer at the beginning of the second growing season should be applied.

Repair

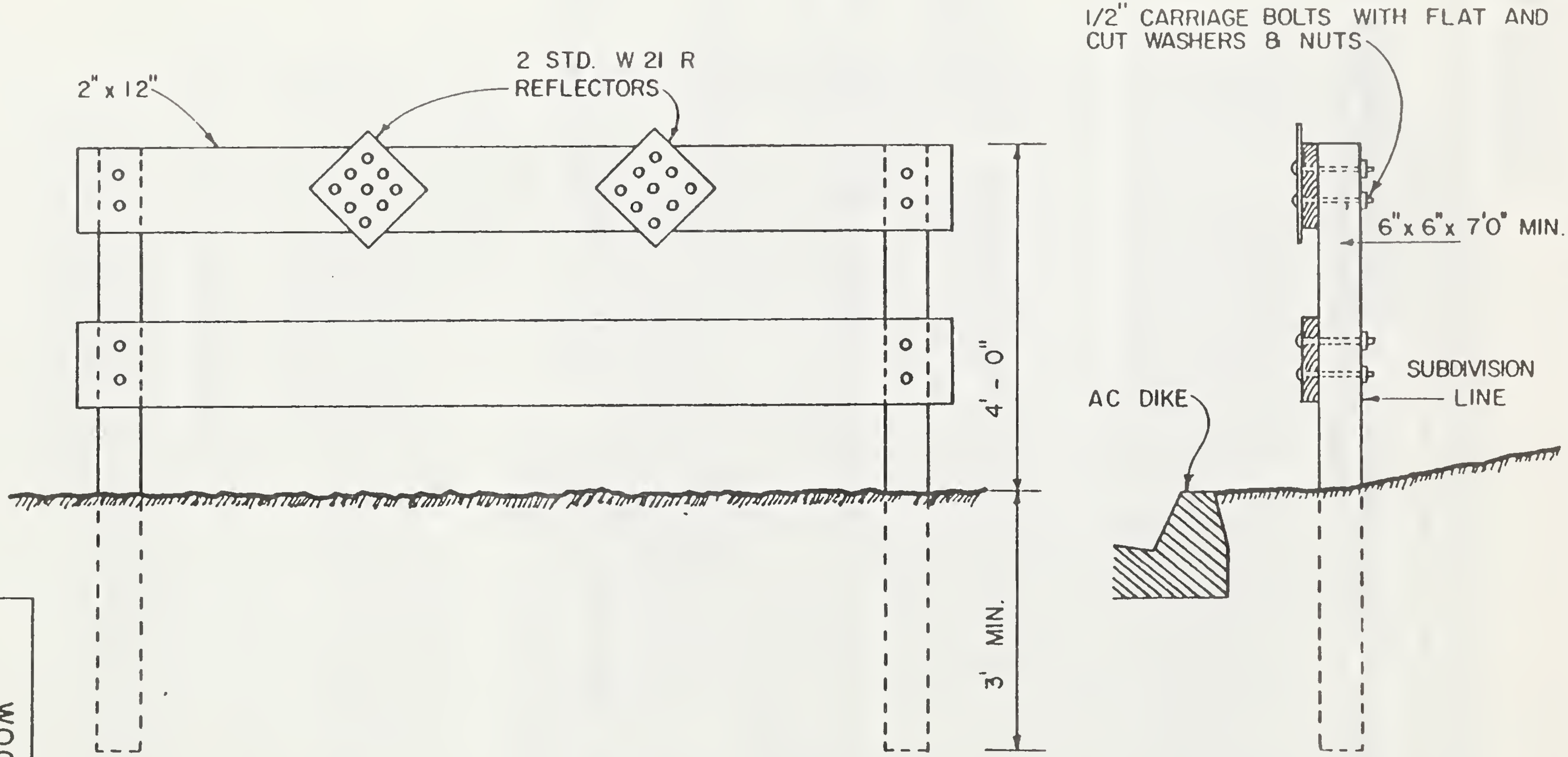
- Some failure of revegetation will certainly occur due to variation in weather, local site conditions and unforeseen damage. If local failures are allowed to persist, progressive failure of larger areas may occur. Early detection and maintenance are necessary to prevent this.

- Reseed, replant and fertilize areas of inadequate plant establishment or damage by surface runoff to original specifications. Water to field capacity to depth of 4 to 5 inches. Inspect frequently following maintenance operations.

- After repair, watering should be conducted to raise the soil moisture to field capacity to a depth of 4 to 5 inches. Such areas should be inspected frequently following maintenance operations.

- Repair areas damaged by frost heave to original specifications, but increase mulch rates by 50 percent. Limit replanting and reseeding to dates between May 1 and August 1.

TYPICAL BARRIER FOR PROTECTION OF REVEGETATED AREAS



BARRICADES SHOULD BE ERECTED AT EACH STREET TERMINAL IN ACCORDANCE WITH THE PROJECT SPECIFICATIONS TO CLOSE STREET COMPLETELY BETWEEN R/W LINES.

EACH UPPER SECTION OF CROSS PIECE POST TO BE EXTENDED 4' ABOVE PAVEMENT SHOULD BEAR TWO STANDARD W 21 R REFLECTORS AS DIRECTED BY THE ENGINEER.

WOODEN BARRICADE
Figure II-10

TOPSOILING

DEFINITION

Placement of topsoil over a prepared subsoil prior to vegetative establishment. Fertile topsoil may be stripped, stockpiled, and later used to supply native seeds to the site.

PURPOSE

To provide a suitable soil medium for vegetative growth on areas with low moisture, nutrient, or pH levels. Also on areas where soil is too shallow to support root systems.

APPLICABILITY

This practice is recommended on slopes 2:1 or flatter where the native soil is unsuitable for vegetative growth.

PLANNING CRITERIA

Care must be taken not to apply topsoil to subsoil of contrasting texture. Clayey topsoil placed over sandy soil for instance, causes topsoil to slough as water flows between soil layers of different permeability.

The following information relates to placement of topsoil.

- Existing or established grades should be maintained.
- Lime may be uniformly applied over designated areas where subsoil is highly acidic or of heavy clay content.
- Prior to spreading topsoil, the subgrade should be loosened by discing or other method to a depth of 2" to permit bonding of subsoil to topsoil. Tracking a bulldozer vertically over the slope will pack the soil and create horizontal erosion check slots to prevent topsoil from sliding down the slope.
- Topsoil should be uniformly distributed at a minimum compacted depth of 2" on 3:1 or steeper slopes and 4" on flatter slopes. Any surface irregularities should be corrected in an effort to prevent formation of water holding depressions.
- Where quantities of stockpiled topsoil on site are limited, it is more desirable to cover all areas of exposed subsoil to a lesser depth than to cover partial areas to the suggested minimum depth of 3".
- Topsoil should not be placed when the subgrade is frozen, excessively wet or in a condition that may otherwise be detrimental to proper grading or proposed sodding.

- If desired, it is possible to place a thin layer of topsoil (one (1) or two (2) inches) on benched slopes. Should this be planned, care should be taken to not apply so much topsoil that the value of the benches is destroyed. This method is especially valuable on rocky benches and particularly south and west facing slopes. From the agronomic view, this is excellent; however, the proper placing of the soil is a very real problem. Soil has been bucketed onto slopes. This gives a rather uneven spread and the quantity is hard to control. Soil has been blown onto slopes with a snow blower. In this case, organic matter may be mixed with the soil. It has been determined that the soil should be screened to remove two (2) inch or larger rocks. The advantages of this method are that the amount of soil needed is much less as it can be spread very rapidly on the horizontal surfaces.

MATERIALS AND METHODS

Topsoil should be a loam, sandy loam, clay loam, silt loam, sandy clay loam, or other mixture approved by an agronomist. It should be free of subsoil, refuse, sticks, noxious seeds, other extraneous materials and stones larger than 1 1/2" diameter. Topsoil must be free of plant or plant parts of quackgrass, poisen ivy, or other vegetative nuisances.

Topsoil can either be stripped, stockpiled, and replaced on the construction site or obtained commercially. Stockpiled topsoil should undergo a laboratory analysis to determine organic content, pH, and soluble salts. A pH of 6.0 to 7.5 and organic content of not less than 1.5 percent by weight is recommended. Where soil pH is less than 6.0, lime may be applied to adjust pH to 6.5 or higher. Soluble salt content greater than 500 ppm should not be used.

CHAPTER III

RUNOFF COLLECTION AND CONVEYANCE

Contents and Applicability

BEST MANAGEMENT PRACTICES (BMP):

III-1 CATCH BASIN. Conducts runoff collected by curb and gutter into storm drainage system.

III-2 CHUTES OR FLUMES. Facilities for conducting water down unstable slopes to stable discharge areas.

III-3 CULVERTS. Conduits used to provide free passage of surface drainage water under a highway, canal or other embankment.

III-4 DIVERSION DIKE/DITCH. For use at the top of cut or fill slopes to divert flows from the slope and onto stable areas.

III-5 DRAIN DIP. A transverse depression constructed across the right of way to divert runoff on unpaved roads.

III-6 DRY WELL. A gravel filled pit or trench for runoff storage and infiltration. Dry wells may be used with catch basins to eliminate local ponding.

III-7 FLEXIBLE DOWNDRAIN. A temporary or permanent drainage facility for use on construction projects. It allows conveyance of stormwaters over unstable slopes to stable discharge areas.

III-8 INTERCEPTOR TRENCH. Used to interrupt long slope faces on relatively gentle slopes (<3:1) and to allow diversion and infiltration of collected runoff and retention of sediments.

III-9 OPEN TOP BOX CULVERT. A temporary or permanent wood (usually) drainage facility installed across unpaved roadways to convey surface stormwater runoff to a downslope drainage collection system.

III-10 ROADSIDE DITCH. To be used alongside roads in limited applications where roadway surface runoff exceeds gutter capacity.

III-11 SILTATION BERM. A temporary, impermeable berm for use on construction sites to retain runoff waters on site.

III-12 PIPE DROP. Used for conducting water down unstable slopes.

III-13 STORM DRAINS. General requirements for sizing and design of all drainage facilities.

III-14 WATERBARS. A transverse berm constructed across the roadway to divert storm runoff away from unpaved road surfaces or other disturbed areas.

III-1

CATCH BASIN

DEFINITION

Facility for conveying runoff collected by roadway collection facilities into an underground drainage system.

PURPOSE

To convey runoff to a pipe system so that gutter flow capacity is not exceeded and to dissipate energy.

APPLICABILITY

To be used along all roadways or other paved surfaces as required.

METHODS AND MATERIALS

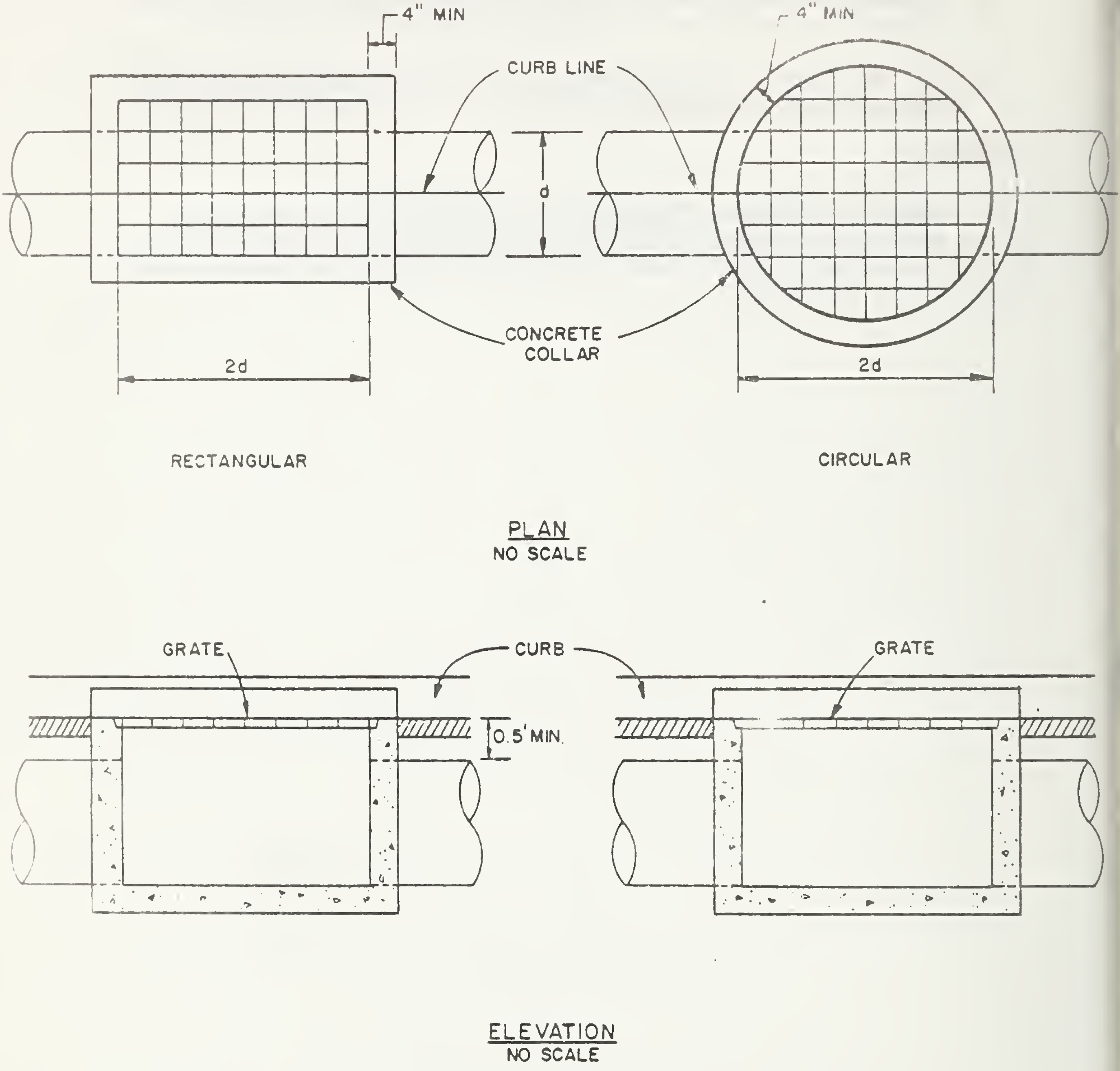
- To be constructed according to local specifications.
- Recommended sections shown in Figure III-1.
- Inlets above fill slopes should be avoided.
- Spacing should be determined so that gutter capacity and catch basin inlet capacity (specified below) are not exceeded and to intercept all drainage.
- Catch basins should be located at all low spots in the street gutter and at abrupt grade changes.
- The gutter flowline may be depressed at inlet points to permit increased gutter grades and reduce ponding.
- Hydraulic grade line should be a minimum of 0.5 feet below the bottom of the inlet grade elevation for the design storm.
- Catch basins should have the following minimum dimensions:
  - Rectangular Inlet - Length of two times inside diameter of pipe, width equal to pipe diameter (18 inches minimum), and depth to allow easy cleaning and maintenance.
  - Circular Inlet - Diameter equal to two times pipeline diameter.

- Capacity of catch basins should be determined by assuming that one-half of the grate is blocked by debris.

- Dry wells may be incorporated into the catch basin design where appropriate, as shown in BMP III-6.

MAINTENANCE

Inlets should be inspected frequently during storms or other runoff periods and debris trapped on the grate or in the inlet removed. Street sweeping should be frequent enough to prevent clogging of catch basin inlets with street debris.



CATCH BASIN
Figure III-1

III-2

CHUTES OR FLUMES

DEFINITION

Concrete channels designed to conduct runoff down a slope face to a stable outlet area.

PURPOSE

To convey surface runoff down a slope face without erosion.

APPLICABILITY

Permanent structures down slopes where concentrated runoff would cause slope erosion. They can be used to convey runoff from diversion dikes, infiltration trenches, slope steps, benches, or other runoff control facilities.

PLANNING CRITERIA

Chutes or flumes are used to convey water collected above a slope down the slope without causing erosion. These structures should be made of durable material and should be designed with adequate capacity to convey the 50-year, 6-hour storm. Detailed design is required.

- The basic design of chutes or flumes is shown in Figure III-2.

- Chutes or flumes should be placed on undisturbed soil or well compacted fill.

- Slopes should be no steeper than 2:1 (horizontal to vertical) nor flatter than 20:1.

- The elevation at the tope of the lining of the inlet structure should not be higher in elevation than the lowest elevation of training berms or other devices that direct flow to the chute or flume.

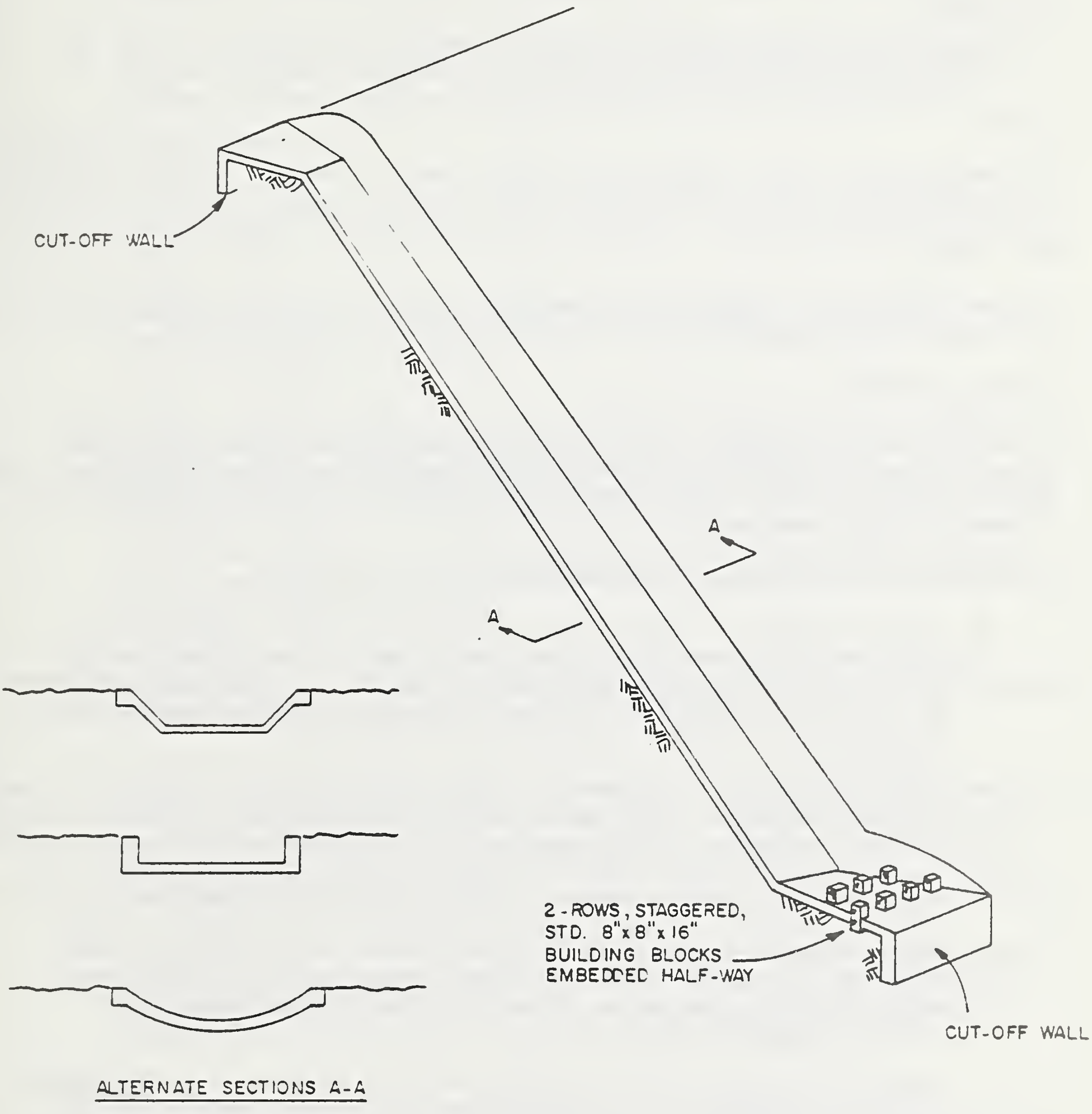
- To insure that a good bond is attained at the interface of the structure and training berms and to prevent piping failure, soil should be compacted around the inlet.

- The outlet structure should be protected against scour with energy dissipators.

- The outlet should be to stabilized area or stable drainage system.

MAINTENANCE

Inspect for damage after each major storm. Inspect for signs of piping failure at interface of entrance structure and training berms. Repair as needed.



CHUTE OR FLUME

Figure III-2

III-3

CULVERTS

DEFINITION

A conduit of corrugated metal or reinforced concrete piping.

PURPOSE

To convey water through embankments, thereby reducing erosion caused by diverted overland flow.

APPLICABILITY

Culverts are used in areas where embankment construction would otherwise disrupt existing drainage patterns.

PLANNING CRITERIA

Culverts to be installed in stream courses should be designed and installed according to Rule #97 of the Stream Channel Alterations, Rules, Regulations, and Minimum Standards, Idaho Department of Water Resources, 1978. (See Appendix III - Volume I of this Handbook).

General factors to consider in culvert design are as follows.

- Culvert Capacity - Based on peak runoff calculations (Appendix A). A 10-year flood capacity without static head at the entrance or 100-year flood utilizing available head at entrance is standard. The shape of the culvert (circular, pipe-arch, arched open-bottom) and number of openings will directly influence design capacities.

- Culvert Alignment - Alignment should provide water with a direct entrance and a direct exit. Sharp turns at the inlet may cause erosion or blocking of inlet by debris. Abrupt changes in flow direction which retard velocity may necessitate design of a larger structure. Steel end sections, riprap, sod, or paving can be used to protect banks from eroding at inlets and outlets. Culverts used for cut and fill drainage on long descending grades should be installed skew across roadway to prevent retarded flow at the inlet. A slight change in the existing channel may be necessary to improve inlet or outlet flow and shorten the required length of pipe.

- Length of Culvert - Culvert length should be determined by alignment and grade in addition to roadway width, fill height above flow line and fill slope grade. For culverts to be installed at right angles to the roadway length can be computed as shown in Figure III-3. (In calculating lengths of skewed culverts, length must be increased according to skew angle.)

- Culvert Grade - Flow line grade within the culvert should be slightly greater than the natural grade to facilitate flow and self-cleaning. On steep slopes, protection is needed against under-cutting at outlets. Culverts placed on high fills or a settleable base should be slightly cambered.

- Debris Control - Debris control measures should be developed as part of culvert design prior to construction. The type of control selected will depend on anticipated debris (logs, limbs, refuse, sediment, rock fragments). A culvert riser (BMP V-3) is a type of debris control.

- Energy Dissipation - Culvert inlets and outlets should be protected from erosive water velocities. Commonly used protective measures include rip-rap, sodding, concrete discharge aprons and gabions.

METHODS AND MATERIALS

Culverts should be carefully transported and placed to prevent structural damage. Installation procedures include excavation, bedding, pipe placement, backfilling and riprapping.

- Excavation - Accurate excavation to line and grade are necessary to ensure efficiency. Trenches should be 12 - 24" wider than culvert to allow for tamping of backfill.

- Bedding - Bedding should afford a uniform, firm bed free of projecting roots, stones or other irregularities for a depth under the culvert of not less than 1/2 inch per foot height of fill over the pipe. Minimum allowable thickness of bedding should be 4 inches. Where such suitable foundation is nonexistent at the established grade, unstable soil under the culvert should be removed and replaced with suitable bedding material. Replaced material should be compacted to support the culvert without settling.

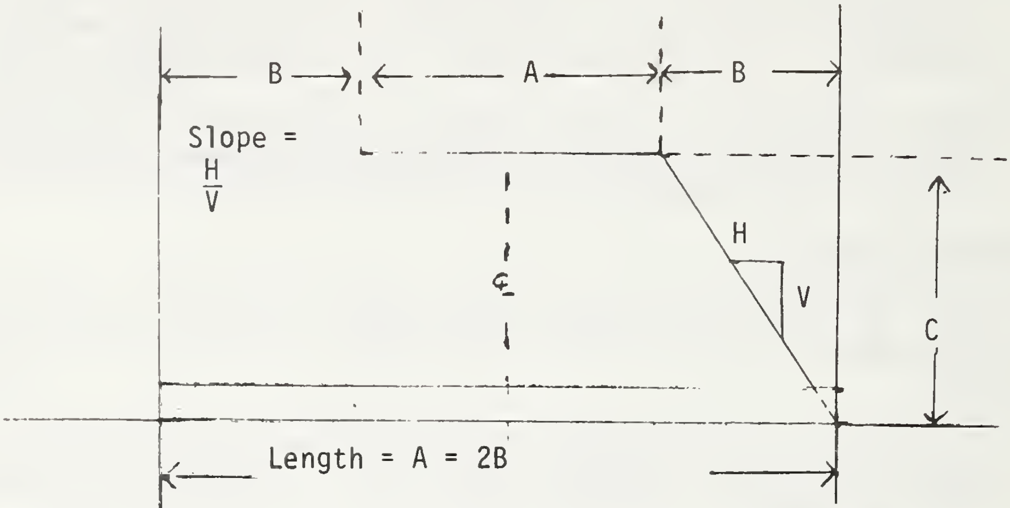
- Pipe Placement - Pipe should be laid with sections joined firmly together with over-laps pointing upstream. Joints should be galvanized or coated with a suitable material for protection.

- Backfilling - Backfill material must be placed and compacted to prevent settling (displacement) and washouts and ensure maximum stability. Backfill should be placed over prepared bed and culvert in layers not exceeding 6 inches in depth and thoroughly compacted. Compaction can be achieved by hand or mechanical means. Backfill layers are placed and compacted separately until embankment is 8 inches above top of pipe.

- Inlet and Outlet Protection - Erosion protection should be provided at inlets using suitable stabilization methods (sod, riprap, headwalls, gabions) and at outlets using energy dissipation or runoff dispersion methods (discharge aprons, riprap, sod, brush filters, etc.).

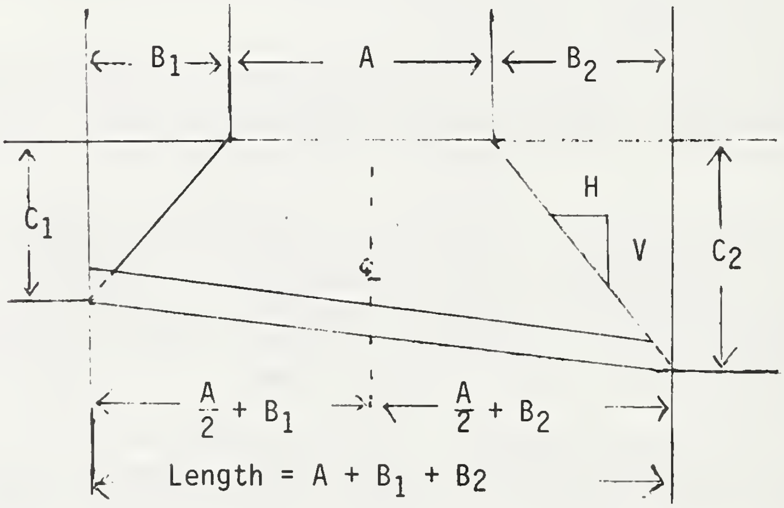
MAINTENANCE

Any culvert which is laid improperly or has experienced settling which decreases design flow efficiency should be re-laid or replaced. Culverts should be inspected for damage and cleaned of debris at least annually and after major storms.



Computation of culvert length--flow line on flat grade

Example: Roadway = 24 ft., Slope = 1 1/2:1, Depth of Fill = 10 ft.
Then B = Side Slope x C = 1 1/2 C
and Length = 24 + 3 x 10 = 54 ft.



Computation of culvert length--flow line on steep grade.

Example: Roadway = 24 ft., Slope = 1 1/2:1,
Depth of Fill - Upstream = 10 ft. Downstream = 15 ft.
Then B_1 = 1 1/2 x C_1 and B_2 = 1 1/2 x C_2
and Length = 24 + 1 1/2 x 10 + 1 1/2 x 15 = 61.5 ft.,
Use 62 ft.

CULVERT LENGTH COMPUTATION

Figure III-3

III-4

DIVERSION DIKE

DEFINITION

A runoff interceptor constructed at the top of cut or fill slopes.

PURPOSE

To divert overland flow away from slopes and reduce uninterrupted slope length.

APPLICABILITY

All slopes which may receive runoff from upslope areas.

PLANNING CRITERIA

Diversion dikes should be placed to intercept all runoff flow from above the cut and fill slopes and upon benches on large slope faces to prevent collected runoff from flowing onto slope faces below.

- Recommended design is shown in Figure III-4-A.
- Diversion outlet must be to heavily vegetated or artifically stabilized areas or to a downdrain, chute or flume.
- Diverted runoff should not overtop the dike.
- General criteria include:
    - Height - 1.5 feet or greater.
    - Top Width - 2 feet.
    - Side Slopes - 2:1 or flatter.
    - Compaction - Should be 85 percent of maximum density.
    - Grade - Dependent upon topography--should be positive.
        - For grades in excess of 2 percent or large flows, the diversion channel requires mechanical stabilization with a concrete, asphalt or riprap lining. Flows concentrated by the diversion dike should be conveyed from the slope using chutes, flumes or pipe drops. (See Figure III-4-B).

- Discharge - Discharge should be to heavily vegetated natural forest area, mechanically and/or vegetatively stabilized area, or drainage system.

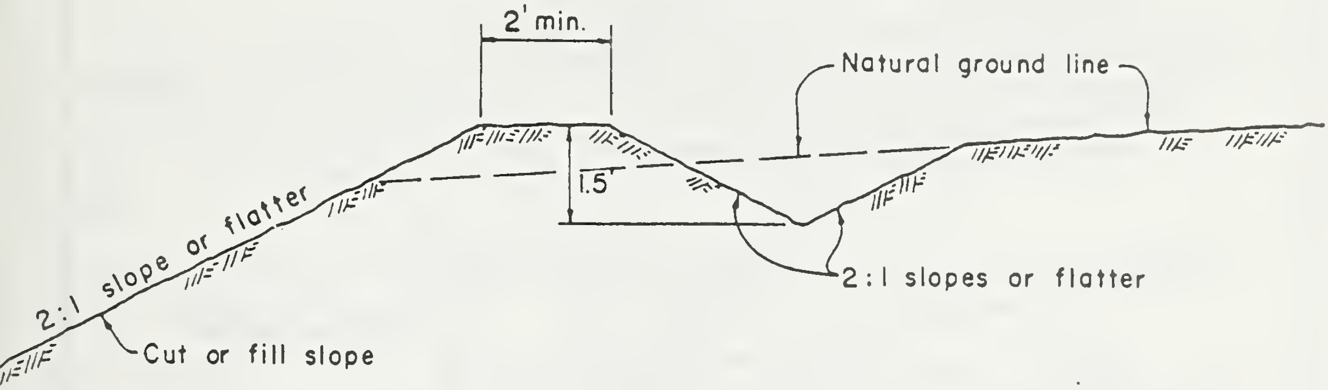
METHODS OR MATERIALS

- The diversion dike consists of a trench and a dike. The trench should be constructed using a dozer blade or hand tools. The dike should be compacted as specified above.

- In wooded areas where top of slope access is limited and anticipated interception of runoff will produce very small flows, diversion dikes can be constructed as a dozer finishes the slope by carrying soil upslope and dumping it at crest. Compaction is sacrificed in this instance. A larger dike is necessary to partially compensate for lack of compaction.

MAINTENANCE

Inspect after each major storm to locate any damaged areas. Repair should be completed before next storm. Any channel obstructions should be removed.



SECTION

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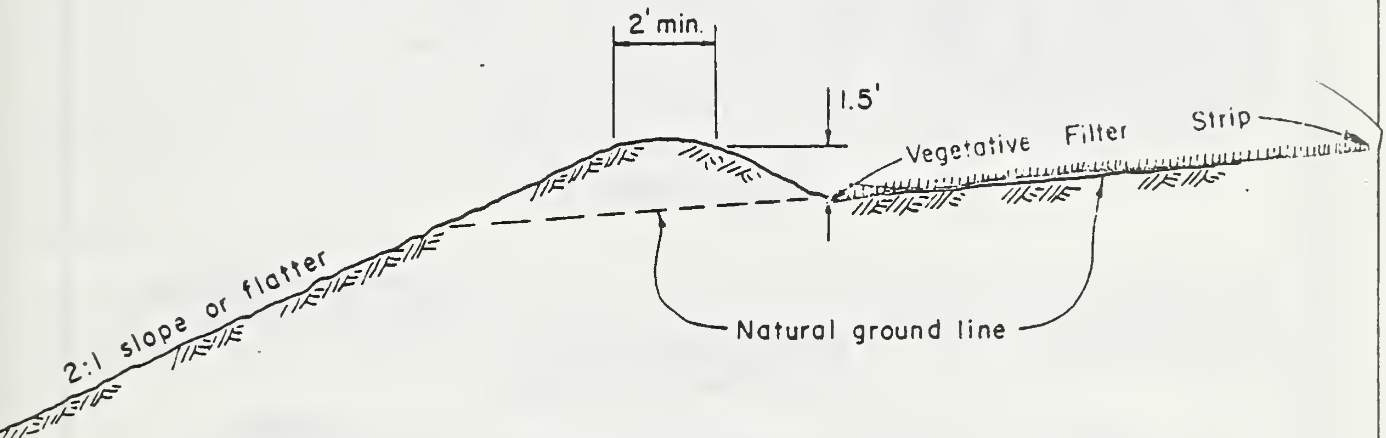


SECTION

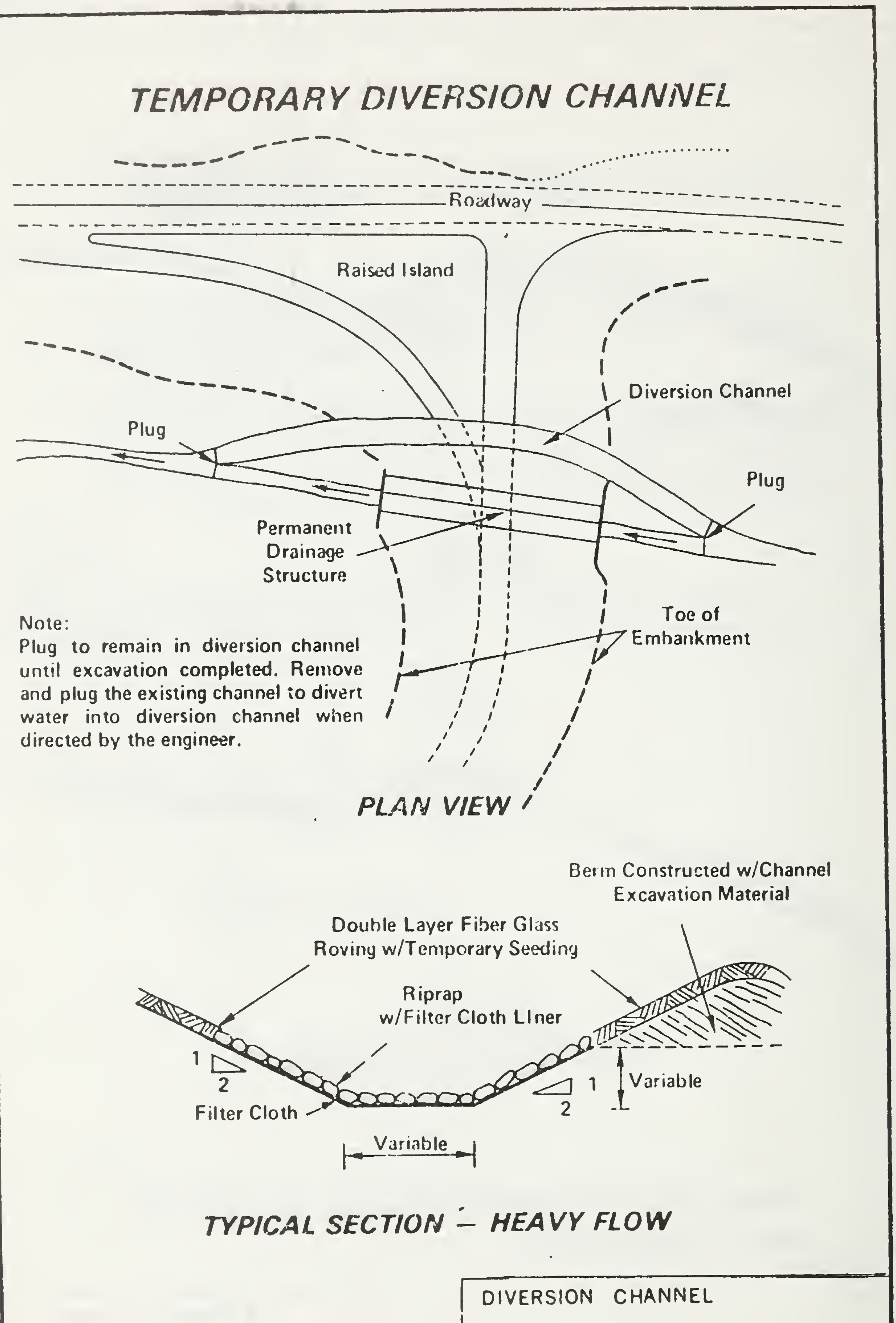
Dike constructed by dozer moving soil upslope and dumping at top of slope.

Diversion dike to be constructed at top of cut or fill slope.

Outlet to stabilized area.

DIVERSION DIKE

Figure III-4-A


TEMPORARY DIVERSION CHANNEL
Roadway
Raised Island
Diversion Channel
Plug
Plug
Permanent
Drainage
Structure
Note:
Plug to remain in diversion channel until excavation completed. Remove and plug the existing channel to divert water into diversion channel when directed by the engineer.
Toe of
Embankment
PLAN VIEW
Berm Constructed w/Channel
Excavation Material
Double Layer Fiber Glass
Roving w/Temporary Seeding
Riprap
w/Filter Cloth Liner
1
2
1
2
Variable
Filter Cloth
Variable
TYPICAL SECTION – HEAVY FLOW
DIVERSION CHANNEL
III-4-B

DRAINAGE DIP

DEFINITION

A broad, shallow depression constructed across a graded, right-of-way.

PURPOSE

To reduce erosion by intercepting storm runoff and diverting it to a safe disposal area.

APPLICABILITY

Dips are used as temporary or permanent drainage control on low-maintenance unpaved roadways where grades do not exceed 10 percent. When properly installed, they do not increase wear on vehicles nor reduce hauling speeds. Dips are installed below outcurves, above incurves, and through fills as needed on either outsloped or insloped roads.

PLANNING CRITERIA

Drainage dips are gently rolling dips installed as roadway construction progresses. Alternating inslope and outslope sections can be built into roads having "rolling grades", providing alternating adverse and favorable grades. A minimum of 50 feet on the uphill approach slope and 15 feet on the slope leaving the dip is suggested to minimize vehicle jolt and prevent wheel tracks from channeling storm water down the roadway. All dips should slope gently between the toe of the road cut and the shoulder of the fill.

METHODS AND MATERIALS

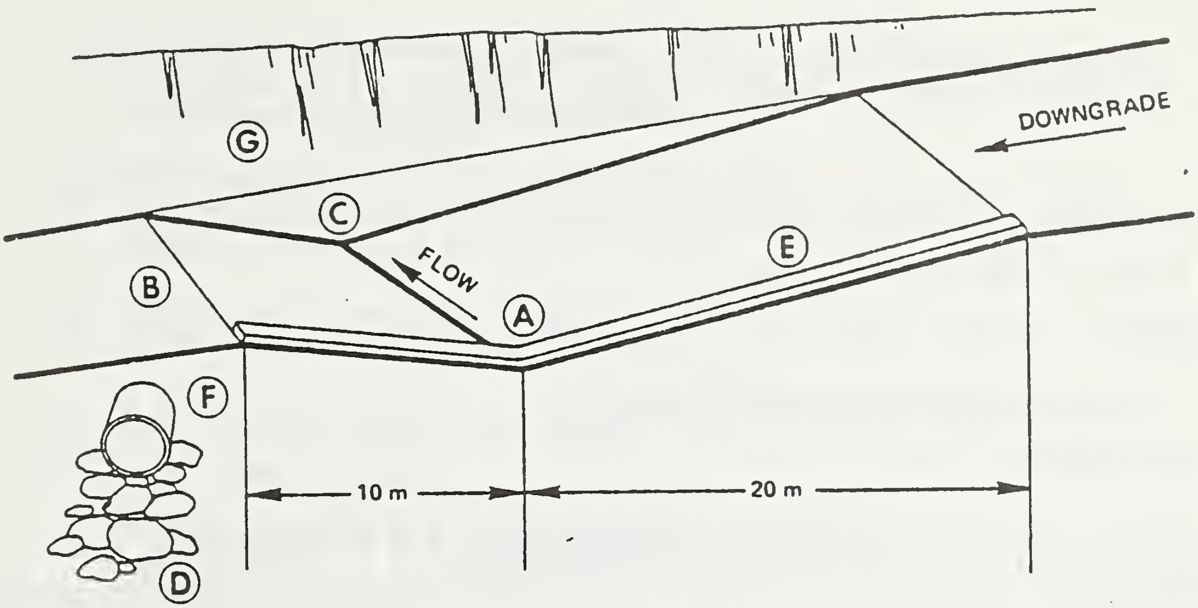
Drainage dips may be either insloped or outsloped depending on site conditions. In either case, it may be desirable to armor permanent dips with crushed rock or gravel. Spacing of dips should be determined as for cross drainage (Appendix E).

- Cutsloping - dips slope toward the downhill side of the road at a 3 - 5% grade relative to right-of-way cross section. It is preferable to insloping because it eliminates the need for drainage facilities as water is dispersed over the fill embankment onto a stable surface (See Figure III-5).

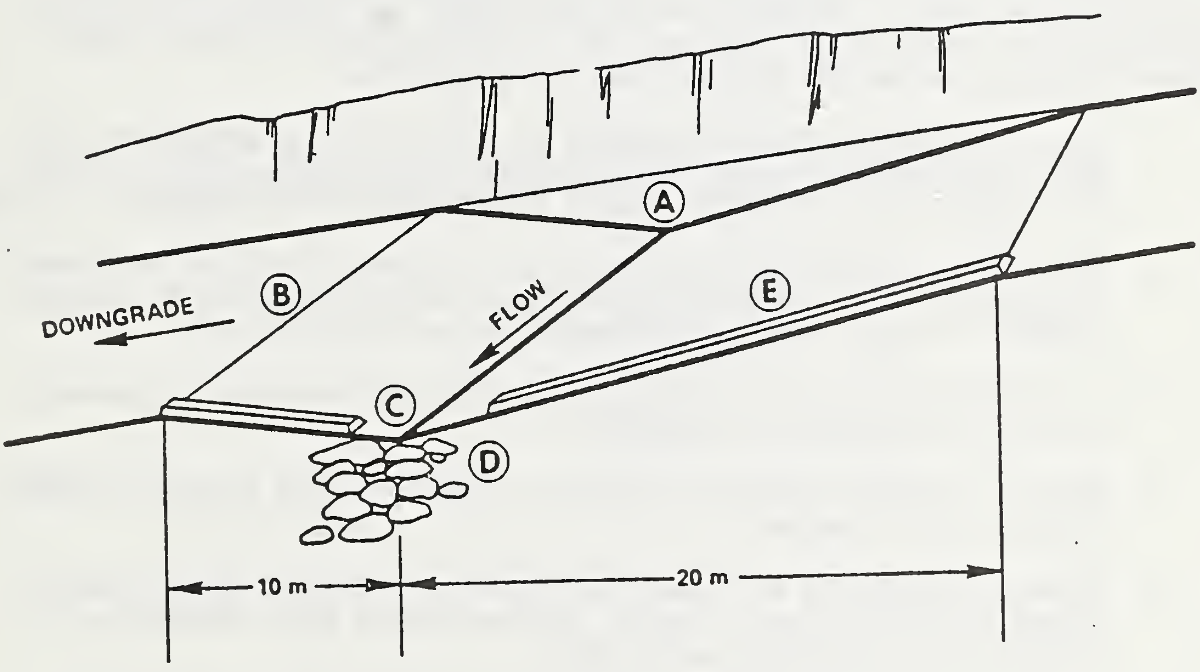
- Insloping - dips slope toward the uphill side of the road and are preferable to outsloped dips where unstable fills exist except in the case of contour roads where no lateral flow occurs along the road. Drainage is carried along the inside of the road surface on ditch to culverts which convey water under the road. Where ditches are used, gradients should be adequate to prevent sediment deposition.

MAINTENANCE

Dips generally require less maintenance and are more permanent than open top box culverts. Drain dips may need to be checked periodically for damage due to vehicular traffic. Ditches should also be checked for obstruction of flow due to sediment deposition. Accumulated sediments or other obstructions should be removed and safely disposed of.



DESIGN OF INSLOPED DIPS. A to C, this slope about 4 - 6 in. to assure lateral flow; B, no material accumulated at this point - may require surfacing to prevent cutting; D, provide rock rip-rap to prevent erosion; E, berm to prevent overflow; F, culvert to carry water beneath road; C, widen for ditch and pipe inlet.



DESIGN OF OUTSLOPED DIPS. A to C, slope about 4 - 6 in. to assure lateral flow; B, no material accumulated at this point - may require surfacing to prevent cutting; D , provide rock rip-rap to prevent erosion; E, berm to confine outflow to 20 in. wide spillway.

DRAINAGE DIPS

Figure III-5

III-6

DRY WELL

DEFINITION

A gravel-filled pit or trench.

PURPOSE

To store and infiltrate surface runoff.

APPLICABILITY

Dry wells can be incorporated into the design of a drainage system to reduce runoff volume and downstream system sizing or as isolated and independent infiltration facilities to eliminate localized flooding or ponding.

PLANNING CRITERIA

Dry wells can provide a very inexpensive means of eliminating isolated flooding or ponding problems in areas with no existing drainage system. They can also be designed into a storm drainage system to provide significant flow reduction and system costs. The decision for use should be based upon soil type and percolation rate, slope, and depth to groundwater in the project area. General planning and design criteria are discussed below.

- Dry wells over 18 feet deep should be constructed in accordance with Rules and Regulations for Waste Disposal and Injection Wells, (Title 42, Chapter 39, Idaho Code), Idaho Department of Water Resources, 1980.

- Dry wells can either be constructed as a gravel-filled pit or trench. Selection of the appropriate type should be based upon soil depth and permeability and level of groundwater in the project area.

- Pit type dry wells can be easily dug using an auger with a standard size hole 18 inches in diameter.

- Dry wells should penetrate at least 3 feet below the expected maximum depth of soil freezing.

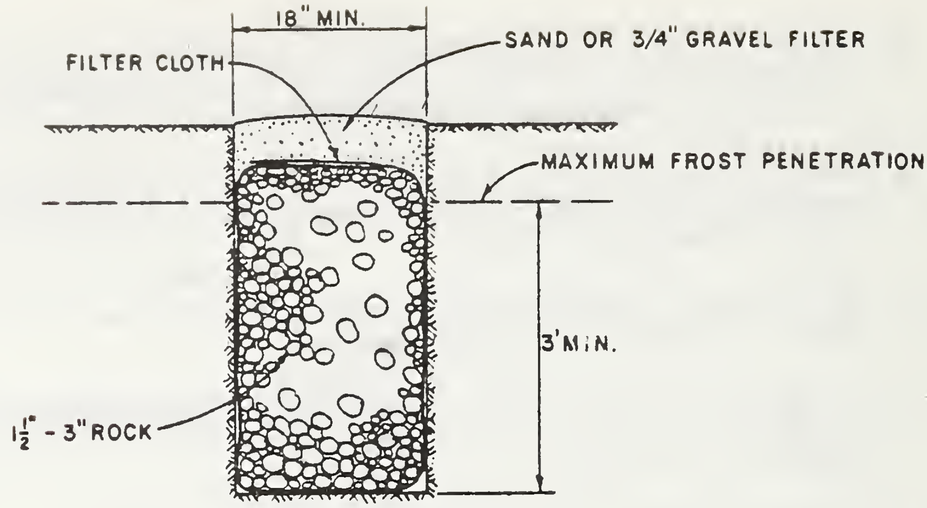
- Several Shallow dry wells more efficiently infiltrate water than one deeper well. Deep wells may be necessary where space limitations prevent use of multiple small wells.

- Trenches dug with backhoes provide more bottom surface area than augered holes. Trenches should be excavated to at least 3 feet below the expected depth of soil freezing.

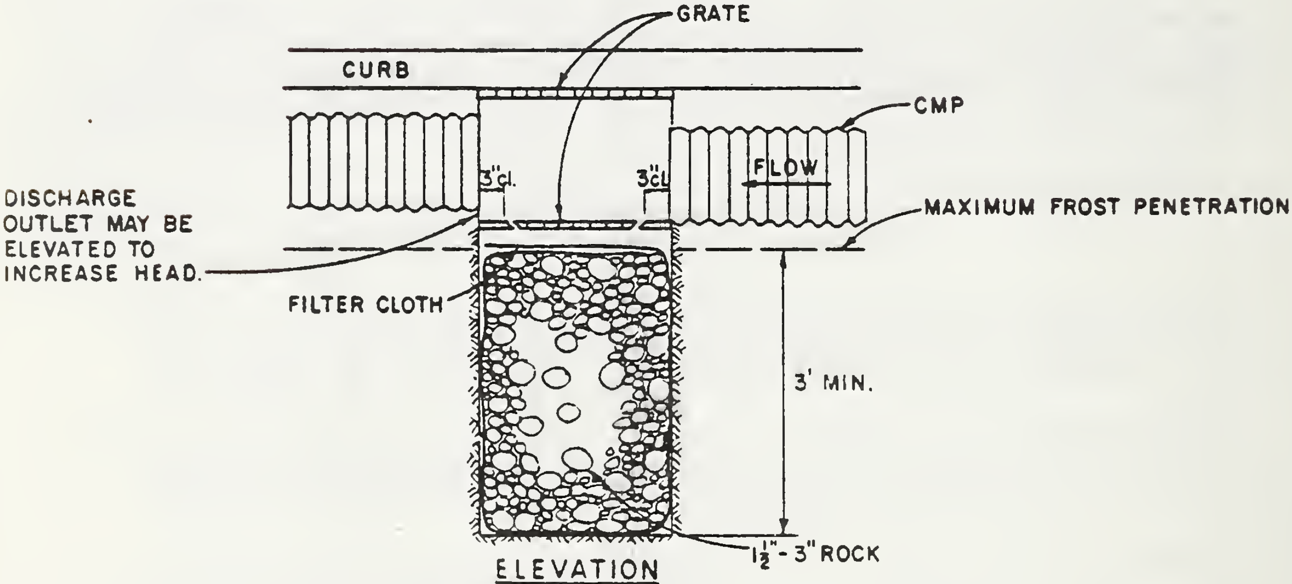
- Dry wells can be incorporated into the design of catch basins and integrated into a drainage system to reduce the required capacity of necessary runoff conveyance facilities.
- When incorporated into a catch basin, the dry well should be equipped with an easily accessible cleanout for removing accumulated sediments and trash.
- The dry well should be filled with 1-1/2 inch to 3 inch rock to within 6 inches of the desired grade.
- A blanket of filter cloth (Mirafi 140 or equivalent) should be placed over the rock, and clean sand or smaller gravel should be backfilled to grade.
- Typical sections are shown in Figure III-6.

MAINTENANCE

Inspection during each major rainfall and snowmelt runoff is mandatory to determine whether the facility is operating. Dry wells associated with catch basins require periodic cleaning. A vacuum truck equipped with a suction nozzle is required to clean out debris and collected sediments.



ELEVATION
WITHOUT CATCH BASIN
no scale



ELEVATION
WITH CATCH BASIN
no scale

DRY WELLS
Figure III-6

III-7

FLEXIBLE DOWNDRAIN

DEFINITION

A conduit of heavy-duty fabric or other flexible material used as a temporary drain to convey water down the face of a slope.

PURPOSE

To convey surface runoff down cut or fill slopes or other steep areas to stable discharge points during construction.

APPLICABILITY

Where runoff water accumulates above cut or fill slopes or slope benches and must be conveyed over the slope.

PLANNING CRITERIA

Flexible downdrains should be installed on slopes immediately after construction and before revegetation of the slope or permanent installation of drainage facilities.

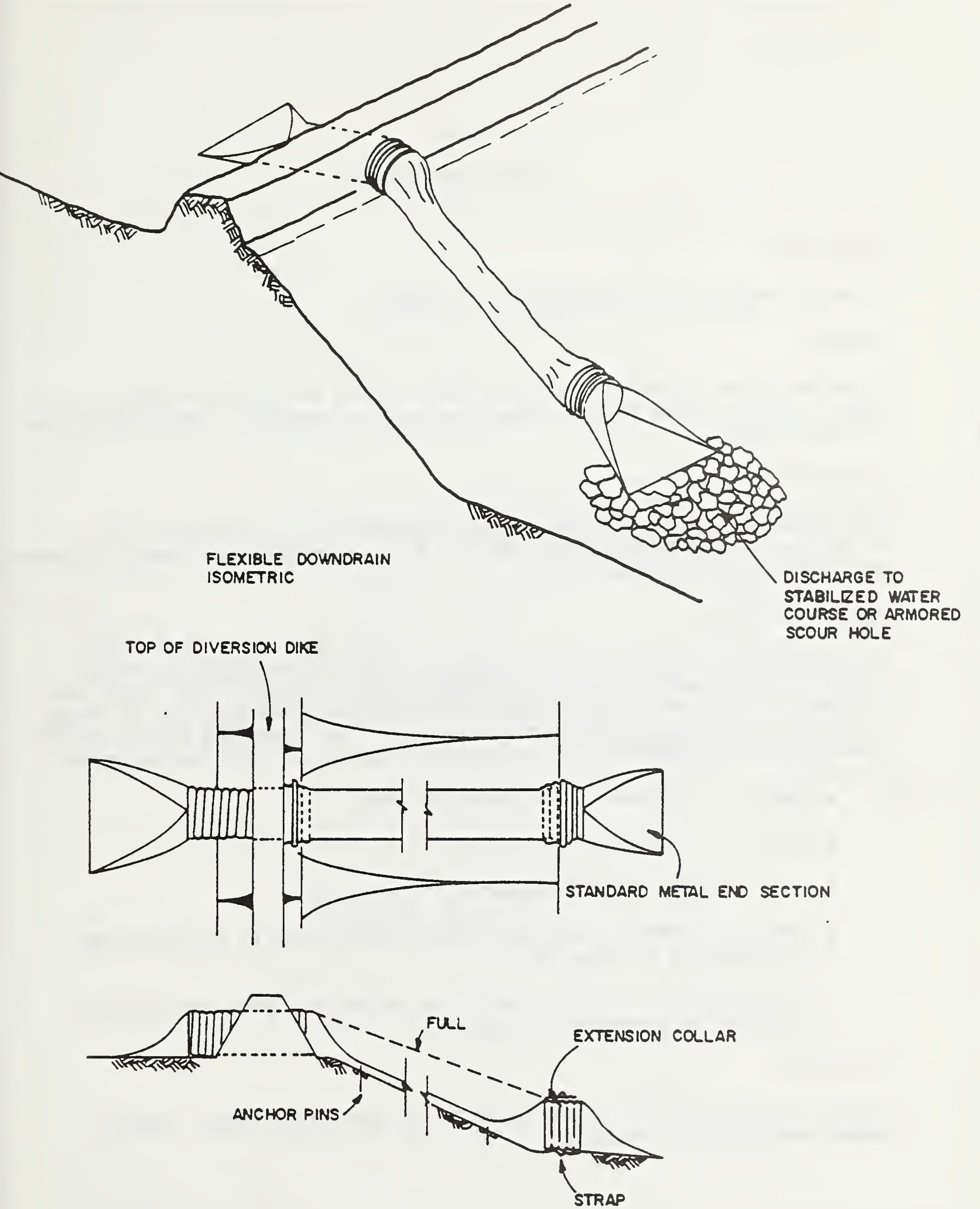
Specific design is not usually required (see Figure III-7).

- Place drains on undisturbed soil or well-compacted fill.
- The diameter should be sufficient to convey runoff from design storm as specified in the regulations.
- Standard metal end sections should be used.
- Extension collars are 12 inches long, corrugated metal pipe of the proper diameter. Do not use helical pipe.
- Flexible conduit should be secured to extension collars with securing straps of fabric, metal, etc., covering at least two corrugations of the extension collar.
- Downdrains should be staked down with metal "T" pins spaced every 10 feet.
- Discharge should be to an energy dissipator or other stabilized outlet.

- No material should be placed on collapsed drain.

MAINTENANCE

- Inspect for damage or clogging after each storm.
- In below-freezing weather, check to ensure that sides of collapsed downdrain are not frozen together.
- Inlet section should be checked periodically for indications of piping along metal sections.
- Resecure anchors and conduct repairs as necessary.



FLEXIBLE DOWNDRAIN

Figure III-7

III-8

INTERCEPTION TRENCH

DEFINITION

A trench constructed along contours of slopes.

PURPOSE

To decrease the uninterrupted slope length, store and divert surface runoff from the slope face to reduce the erosion potential from concentrated surface runoff.

APPLICABILITY

Used on slopes with comparatively gentle gradients (3:1 or less), but having long uninterrupted slope lengths; e.g., abandoned dirt roads, easements, and gently sloping cuts and fills.

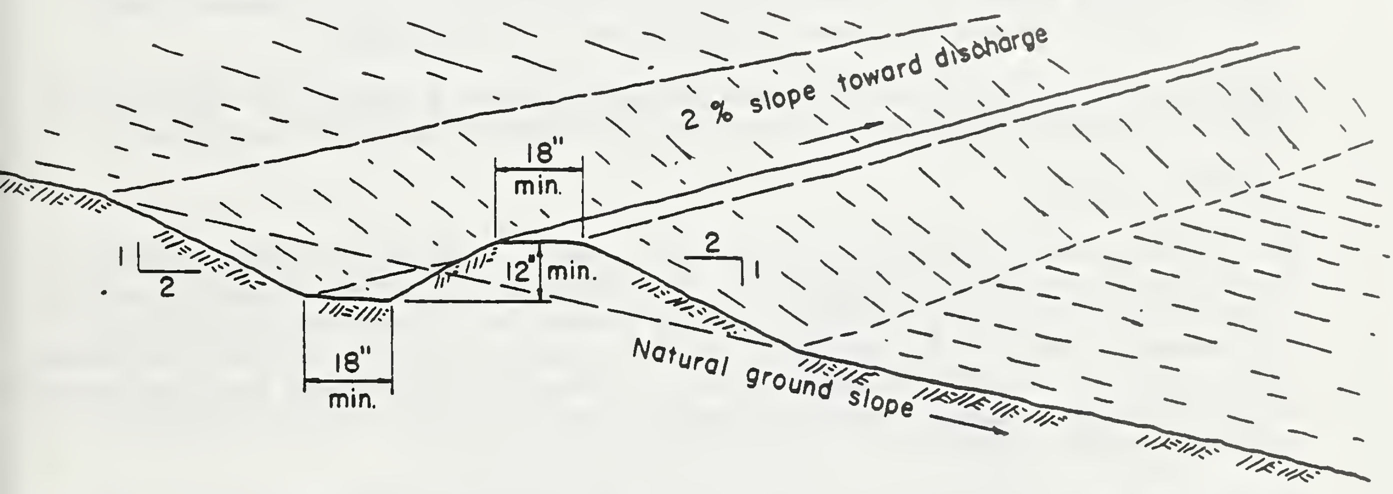
PLANNING CRITERIA

The recommended design is shown in Figure III-8. Construct the trench along the slope contour with outlet to a level spreader or other stabilized discharge. Excavated material should be placed on downslope side of trench and spread to conform with the natural slope. The trench and the surrounding slope should be stabilized and revegetated immediately after construction.

- Depth - 12 inches at the downslope edge.
- Width - 18 inches at the bottom.
- Side Slopes - 2:1 or flatter.
- Grade - 2 percent slope away from slope centerline to stabilized discharge or drainage facility.
- Trench Spacing - Spacing should be determined using the method of calculation presented in Appendix C.

MAINTENANCE

Inspect for damage after spring snowmelt and each major storm. Repair damage immediately as required.



ISOMETRIC SECTION
not to scale

RUNOFF INTERCEPTOR TRENCH
Figure III-8

III-9

OPEN TOP BOX CULVERT

DEFINITION

A wooden culvert installed across haul roads to convey surface runoff and side ditch flows to the downslope side.

PURPOSE

To collect and direct road surface storm runoff and upslope side ditch flows across roads without eroding the drainage system or road surfaces.

APPLICABILITY

This type of culvert may be used for cross drainage on lightly used, unpaved roads on steep grades as a substitute for pipe culverts. This method should not be used for handling streams on skid trail cross drainage.

Generally, box culverts are not required on grades of 6 percent or less and are ineffective under continuous or recurrent use where cleaning is sporadic.

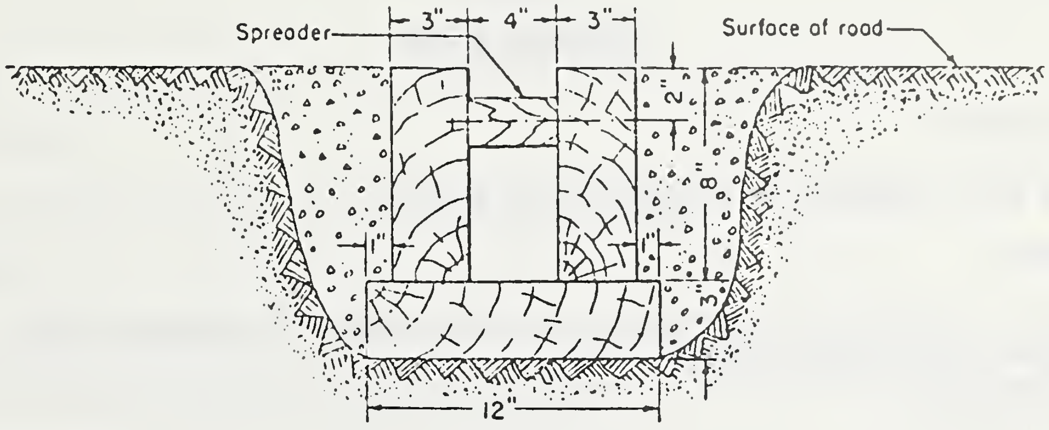
PLANNING CRITERIA

Box culverts may be constructed with logs, lumber, discarded highway quadrails, or commercial corrugated steel, etc. They consist of box-like frames (open top) installed flush with the road surface and skewed at an angle downgrade across the roadway. The invert end should be at a grade with the side ditch and extend into the toe of upslope caste. The outfall should extend beyond the road surface and be afforded adequate erosion protection using riprap or other materials to dissipate water velocities. (See Figure III-9).

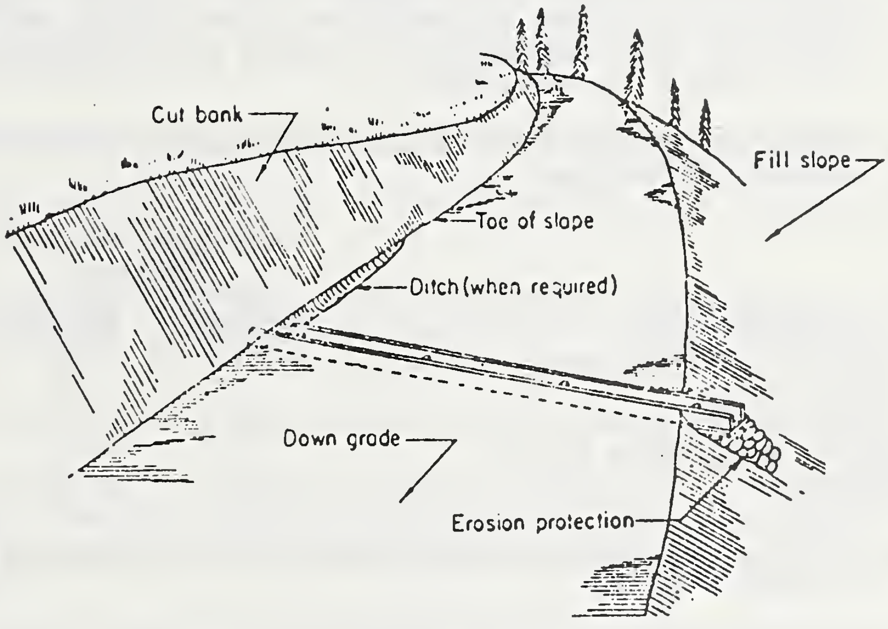
Spacing between culverts should be in accordance with recommended cross drainage spacing in Appendix E. Where recommended spacing is less than 30 feet, the road should be paved with gravel or crushed rock.

MAINTENANCE

Regular maintenance is required to remove sediments and other debris which may block drainage flows and decrease structural efficiency.



END VIEW



METHOD OF INSTALLATION

OPEN TOP BOX CULVERT

Figure III-9

III-10

ROADSIDE DITCH

DEFINITION

Side ditch adjoining the shoulder of a road.

PURPOSE

To carry excess road runoff and to prevent erosion from uncontrolled surface flows along roadway.

APPLICABILITY

To be used only in limited locations where surface runoff from the adjacent roadway surface exceeds the gutter capacity or where gutters are inappropriate or not required. This method of drainage control should not be used as a major drainage channel.

PLANNING CRITERIA

- Ditch sections should be subject to permit-issuing authority approval as to slope, cross-section, size, lining, and location within the road right-of-way and should provide hydraulic capacity on at least a 10-year storm.

- Ditches can either be lined or unlined subject to the following permitted velocities:

Channel Type	Permitted Velocity (ft/sec) Minimum	Maximum
Unlined Earthen Ditch	1	2
Riprap Lining	3	10
Grouted Riprap Lining	2	12
Asphalt or Concrete Lined	2	15
Vegetation	2	4

- Lining of ditches should be compatible with procedures described in these standards.

- In those areas where natural hydraulic conditions dictate velocities in excess of the above standards, grade control structures such as check dams or drop structures should be utilized or stable drainage systems should be installed.

MAINTENANCE

Inspect periodically for damage and repair as required. Keep ditch clear of debris.

III-11

SILTATION BERM

DEFINITION

An impermeable barrier around construction sites.

PURPOSE

To capture and contain runoff from a construction site, to allow sediments contained in the runoff to settle out, and to direct runoff water through filter berms on outlets to stable drainages.

APPLICABILITY

Siltation berms should be placed on the downslope sides of construction sites.

PLANNING CRITERIA

Berms should be sized to contain the runoff water from the selected design storm.

METHODS AND MATERIALS

Siltation berms should be constructed of the following materials:

- 3/4 to 1-1/2 inch gravel, or coarse soil material from the site, if available.
- Plastic sheeting, 6 mil thick, VisqueenR or equivalent, in widths great enough to cover the berm and allow 2 feet of additional plastic sheeting on each side of the berm.

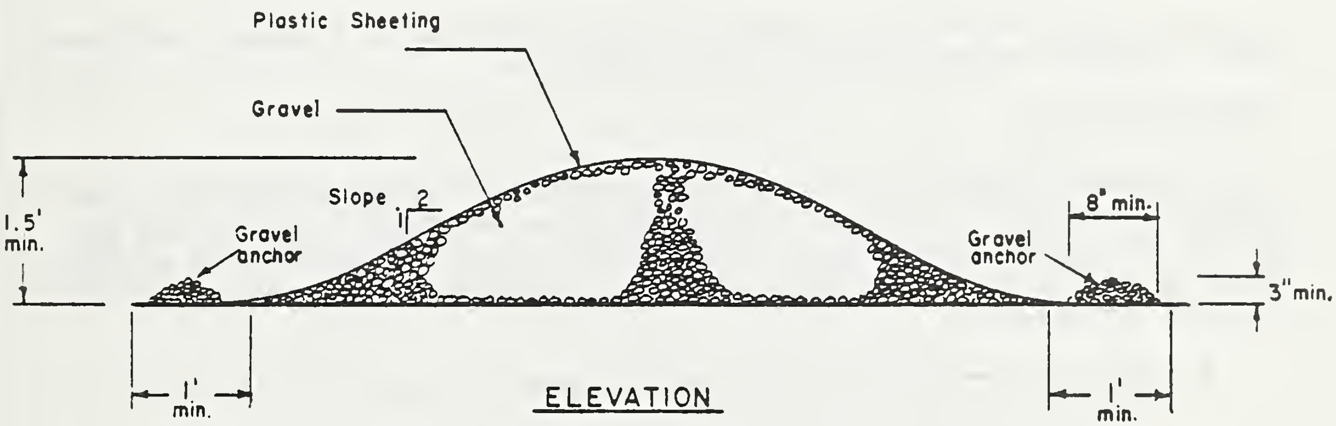
The construction procedure should be as follows:

- The berm should be located along the contour of the slope at the downhill margin of the construction site using a hand level. It should be marked using stakes, lime lines or other appropriate method.
- All trash, debris, forest duff, and materials which could lead contained stormwater under the berm should be removed from the location the berm is to occupy.

- Gravel or coarse soil material should be mounded into a ridge of sufficient height to contain the specified volume of stormwater. The sides of this ridge should not exceed 2:1 slopes.
- Plastic sheeting should be placed over the berm so that it overlaps equally on either side of the berm. Where one sheet of plastic ends and another is begun, the overlap of the ends should be at least 4 feet.
- Plastic sheeting should be anchored with 1-1/2 inch or 3/4 inch gravel, not coarse soil material. Gravel should be placed on the edges of the plastic sheeting to a depth of at least 3 inches and a width of at least 8 inches (refer to Figure III-11).

MAINTENANCE

Siltation berms should be inspected periodically and maintained or repaired in a manner sufficient to meet the intent of this Best Management Practice.



SILTATION BERM

Figure III-11

III-12

PIPE DROP

DEFINITION

A pipe from the top to the bottom of a slope.

PURPOSE

To convey surface runoff down a slope to a stable outlet area to prevent erosion of the slope face.

APPLICABILITY

To convey runoff gathered by diversion dikes, infiltration trenches, horizontal steps, or other surface runoff control facilities.

PLANNING CRITERIA

The conveyance of water in a stabilized system from the top of a slope to the bottom is necessary to prevent erosion and to ensure slope stability and the success of revegetation efforts. Inadequate placement or maintenance of pipe drops can result in the failure of both the pipe drop and the slope stabilization and revegetation.

- The basic design for a pipe drop is shown in Figure III-12.
    - Detailed design for pipe drops should be obtained and caution must be used in construction to prevent runoff water from avoiding the pipe drop and flowing down the face of the slope.
    - Temporary pipe drops should be designed for the peak runoff from a five-year, six-hour storm.
    - Pipe drops should be designed for the peak runoff from a 50-year, 24-hour storm.
- Stable inlet and outlet structures should be provided.
    - The pipe drop inlet should be constructed of concrete.
    - Outlet protection should be provided by riprap or other means of energy dissipation.
    - Thrust blocks should be placed at all grade changes.

- Antiseep collars should be placed at intervals no greater than 20 feet along the pipe drop.

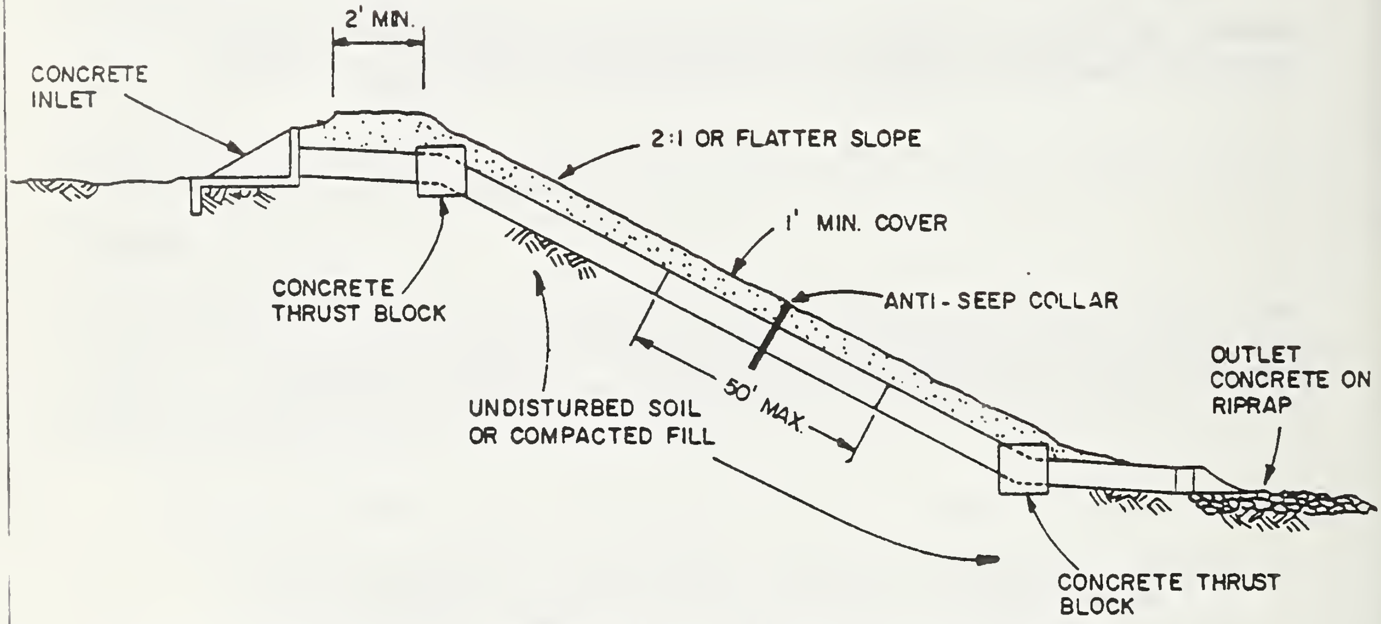
- The inlet structure should be designed for the design storm with a safety factor of 1.5 to prevent overtopping of the slope.

- The pipe drop should be constructed in the slope using adequately compacted backfill.

- Concrete or riprap should be installed at the inlet and outlet as necessary to prevent soil erosion.

MAINTENANCE

Inspect for damage or clogging after each major storm. Inlet section should be inspected periodically for indications of piping.



NOTE: Rip-rap shall be 6" layer of 4" min. dimension rock or rubble with 3" sand bedding.

PIPE DROP

Figure III-12

III-13

STORM DRAINS

DEFINITION

Pipes, channels or other facilities used to collect and/or convey surface runoff.

PURPOSE

To convey surface runoff concentrated by natural drainageways, curb and gutter, or other small runoff collection facilities to a stable discharge point.

PLANNING CRITERIA

<u>General</u>

- System sizing should be compatible with the hydrologic calculation procedures presented in Appendix A.
- All natural drainageways originating outside the project area should enter and leave the project area at the original horizontal and vertical alignment.
- Storm drainage facilities (excluding cross-culverts) should be parallel with the street centerline wherever possible.
- Large angular changes in alignment of any drainage facilities are to be avoided and no change should exceed 90 degrees.
- Vegetation should be established and street surfaces should be repaired on all disturbed areas immediately after drainage system construction following procedures outlined in BMP Chapter II.

<u>Closed Conduits</u>

- Minimum diameter of closed conduits should be 18 inches unless otherwise approved by the permit-issuing authority.
- Underground pipe systems are preferred to surface systems in heavily developed commercial or residential areas.
- Direct transitions from a larger upstream pipe diameter to a smaller downstream diameter should not be permitted even for slope changes because of the possibility of clogging, unless a special transition structure is provided.

- The crowns of all pipe sections should be matched at any transition points.
- Debris control measures such as trash racks should be incorporated into drainage system design in those locations where system failure from clogging could cause damage from flooding or erosion.
- Inlets and outlets of culverts and storm drains should be equipped with wingwalls and aprons as required to prevent erosion and undermining as specified in BMP IV-2. A typical outlet section is shown in Figure IV-2-B.
- Perforated pipe encased in a gravel-filled trench may be used as soil conditions permit to promote infiltration of surface runoff and to reduce surface flows.
- Sediment and flow detention basins (BMP IV-1) should be incorporated into storm drainage systems wherever possible to reduce peak flows and keep sediment materials from clogging downstream drainage facilities.

MAINTENANCE

Periodic inspection and repair are required to keep all runoff conveyance systems operable. Regular street sweeping is mandatory to prevent the deposition of large solids in pipes, ditches and inlet structures and to prevent system clogging.

WATERBARS

DEFINITION

A berm constructed at a downward angle across the roadway and continuous with cutbank and fill shoulder.

PURPOSE

To reduce erosion by diverting stormwater runoff from the road surface to a safe discharge area.

APPLICABILITY

Used as temporary or permanent drainage facility on light - use, low-maintenance, unpaved roads.

PLANNING CRITERIA

Waterbars should be placed above grade changes to prevent water from flowing down steeper portions of roads or skid trails. Bars may also be placed above intersections of roads, skid trails or landings to protect these disturbed areas. The size of the water bar will depend on the amount of precipitation, soil erodibility, and anticipated traffic. Spacing between bars can be determined using Appendix E - Cross drain spacing. Runoff should not be directed onto fill material without proper energy dissipation and drainage away from fill.

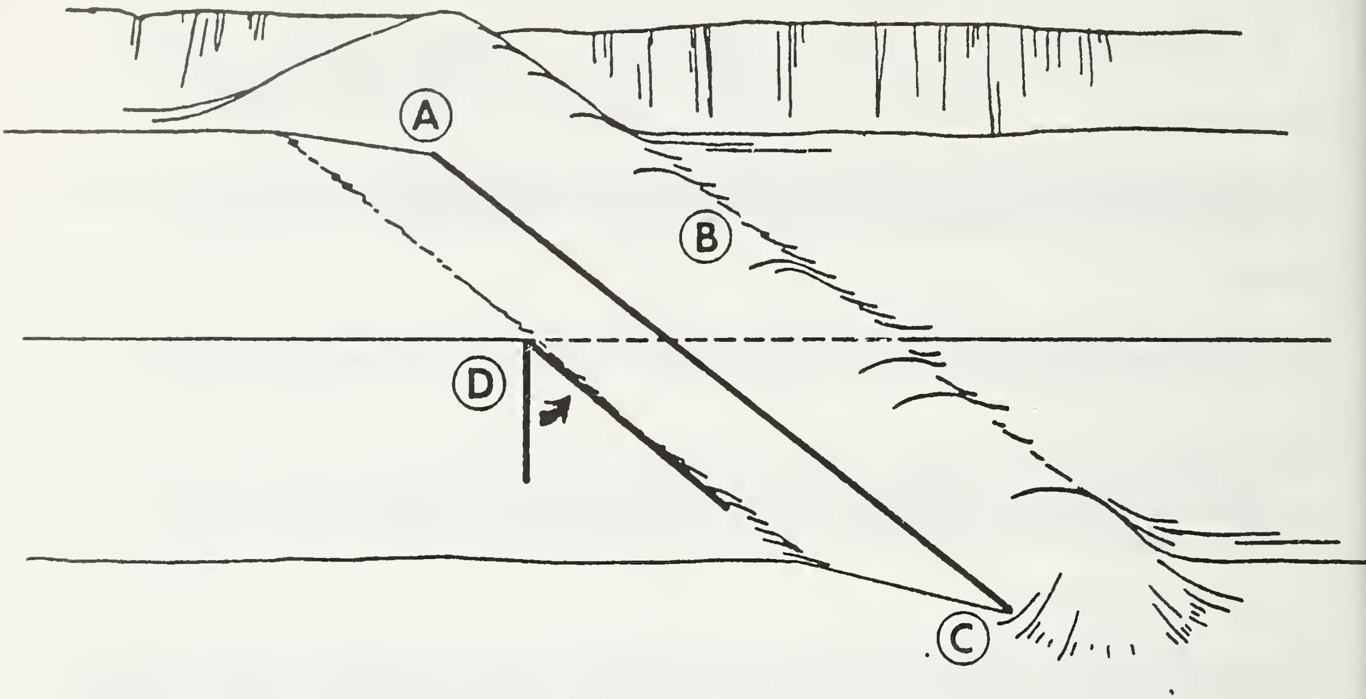
METHODS AND MATERIALS

Waterbars are generally constructed using a blade-equipped tractor or by hand. Each bar should be cut into solid soil to a minimum depth of 6 inches next to the cut bank and 8 inches at the road shoulder with an adverse grade on the down-road or downgrade side of the waterbar. A continuous firm berm of soil should be built at least 6 inches above the normal road grade downhill and parallel to the waterbar cut. Bars may be compacted with a non-erosive fill material for added stability. The bar should extend the full roadway width and be aligned at a 30-45^{o} angle relative to the roadway. (See Figure III-14).

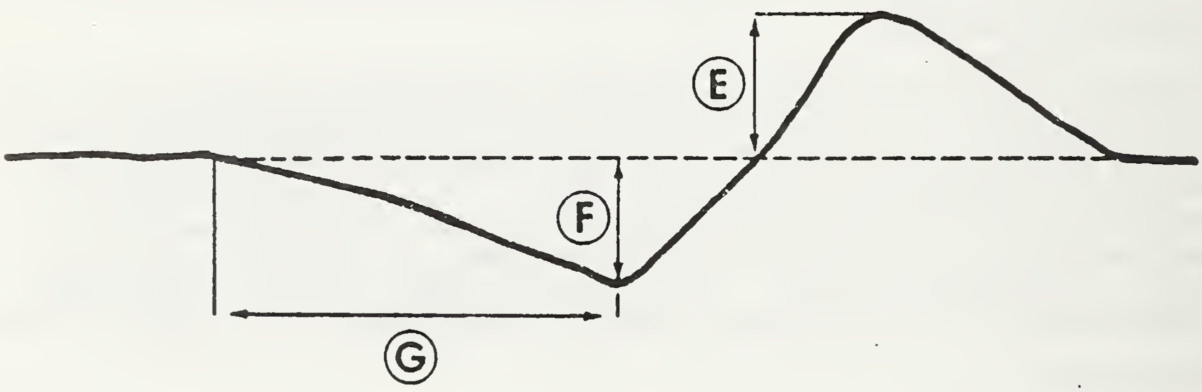
MAINTENANCE

Properly constructed bars are intended to be self-maintaining. However, all waterbars need to be open at the lower end so water can easily flow away from the roadway. Hand shovel work may be necessary following high runoff periods or severe storms to insure unrestricted flow.

TOP VIEW



CROSS-SECTION AT CENTER LINE



WATERBAR (CROSS DITCH). Construction for unpaved forest roads with limited or no traffic. Specifications are average and may be adjusted to gradient and other conditions. A, bank tie-in point cut 6 to 12 in. into roadbed; B, cross drain berm height 12 to 24 in. above road bed; C, drain outlet cut 8 to 16 in. into road; D, angle drain 30° to 40° downgrade with road centerline; E, height up to 24 in., F, depth to 18 in.; G, 36 to 48 in.

WATERBAR or CROSS-DITCH

Figure III-14

CHAPTER IV

RUNOFF DISPERSION AND DISSIPATION

Contents and Applicability

BEST MANAGEMENT PRACTICES (BMP):

IV-1 CHECK DAM. Small dams or drop structures used in open drainage facilities to decrease runoff velocity, minimize channel scour, and promote sediment deposition.

IV-2 DISCHARGE APRON AND ARMORED SCOUR HOLE. Provides protection against erosion at the discharge outlet of runoff conveyance facilities.

IV-3 DROP INLET. Protects inlet channels against erosion.

IV-4 EROSION CHECK. Permeable barriers installed in drainage facilities or on slopes to provide grade control and retard rill and gully formation.

IV-5 CHANNEL PROTECTION - RIGID LININGS. Use of rock or concrete mixtures for soil stabilization.

IV-6 CHANNEL PROTECTION - MATTING. Methods for applying jute matting or fiberglass roving for temporary dust and erosion control in open drainage channels.

IV-7 LEVEL SPREADER. Used to spread concentrated flows into sheet flow for discharge into stable areas.

IV-8 SLOPE SERRATION (SCARIFYING). Small steps on a slope face which are useful for providing small favorable sites for vegetative establishment. Limited to soils which have medium to high cohesion properties.

IV-9 SLOPE STEPPING (BENCHES). Large steps in a slope face useful for establishing favorable sites for vegetative establishment and for stabilizing large oversteepened slopes in highly cohesive material. Most applicable to new construction.

IV-1

CHECK DAM

DEFINITION

Small dam or drop structure constructed in an open channel or drainageway.

PURPOSE

Used to reduce or prevent excessive bank and bottom erosion by reducing the gradient and/or runoff velocity in drainageways, swales, or channels.

APPLICABILITY

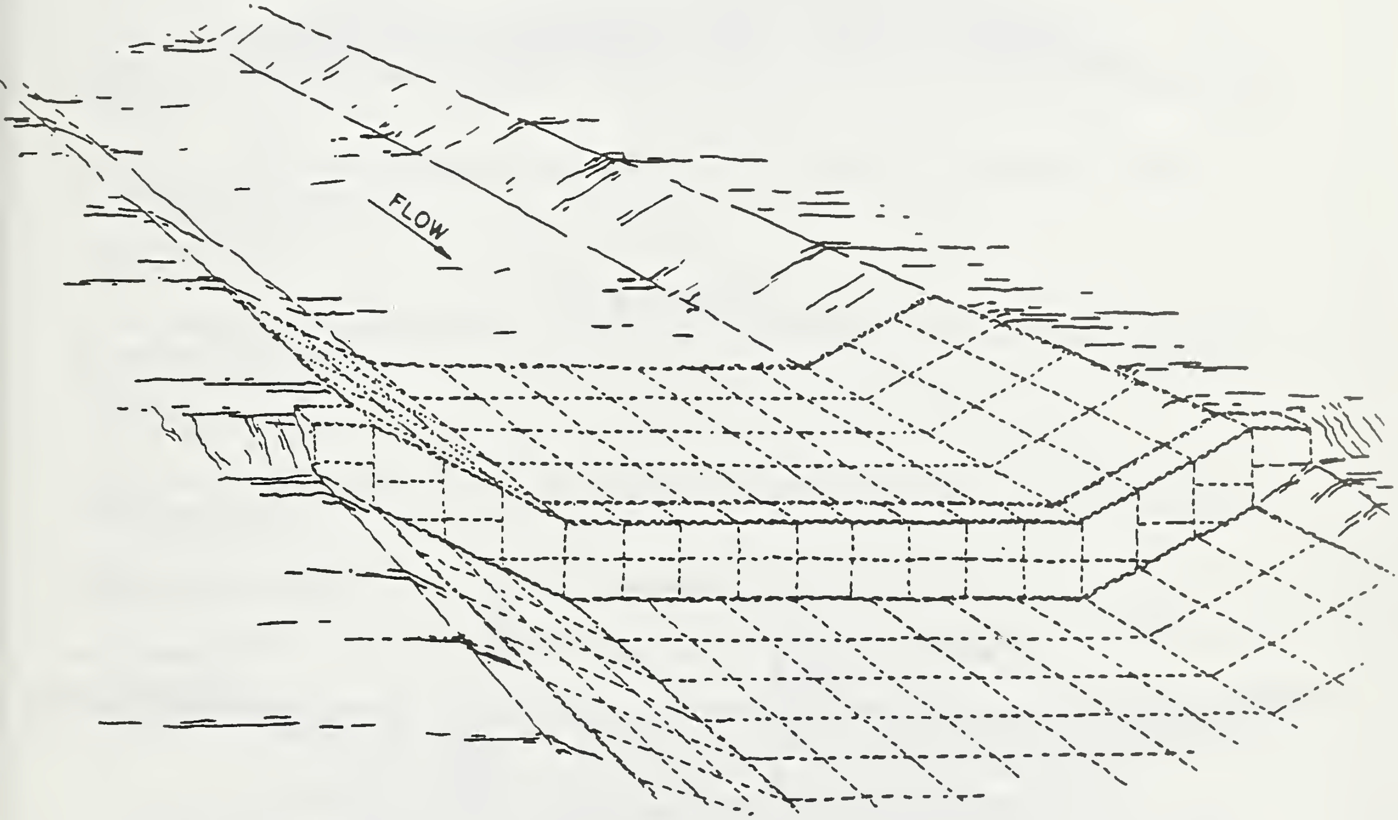
As required in channels or drainageways to reduce excessive grades and velocities and prevent erosion.

PLANNING CRITERIA

- Design by an engineer generally is required. Typical sections using gabions or brush/logs are shown in Figures IV-1-A and IV-1-B respectively.
- Overfall structures may be constructed of concrete, metal, rock, gabions, wood, or other durable material.
- Check dams should be located in a reasonably straight channel section.
- Site and foundation conditions and aesthetic considerations are important factors in construction material selection.
- Design channel grade above and below the structure should be analyzed to determine if erosion or sediment deposition will be a problem.

MAINTENANCE

Generally not required.

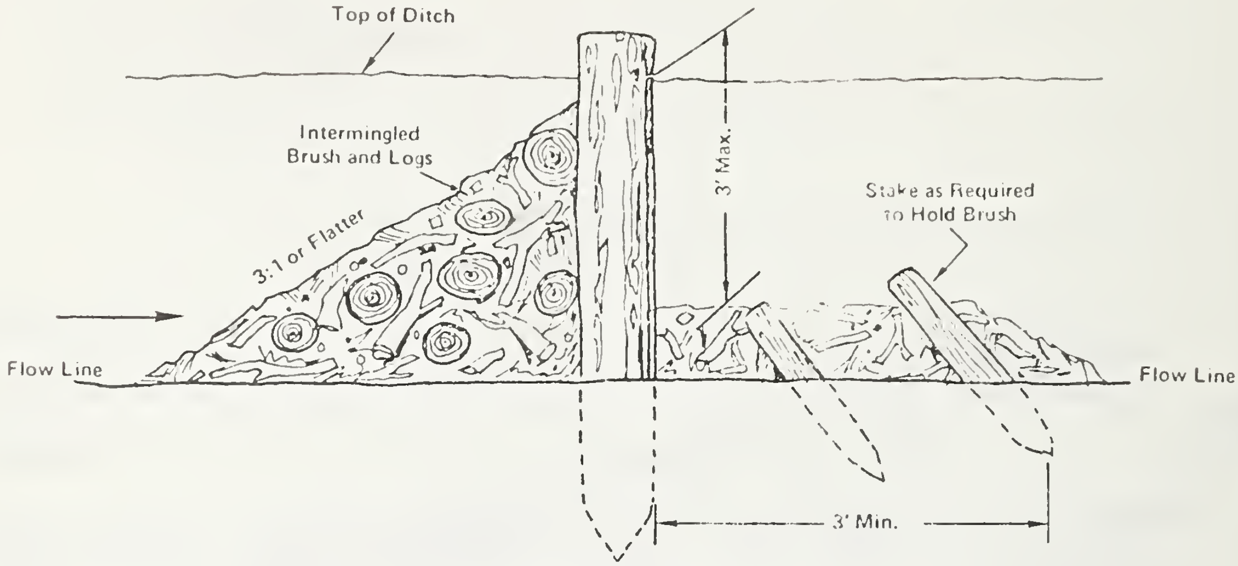


ISOMETRIC

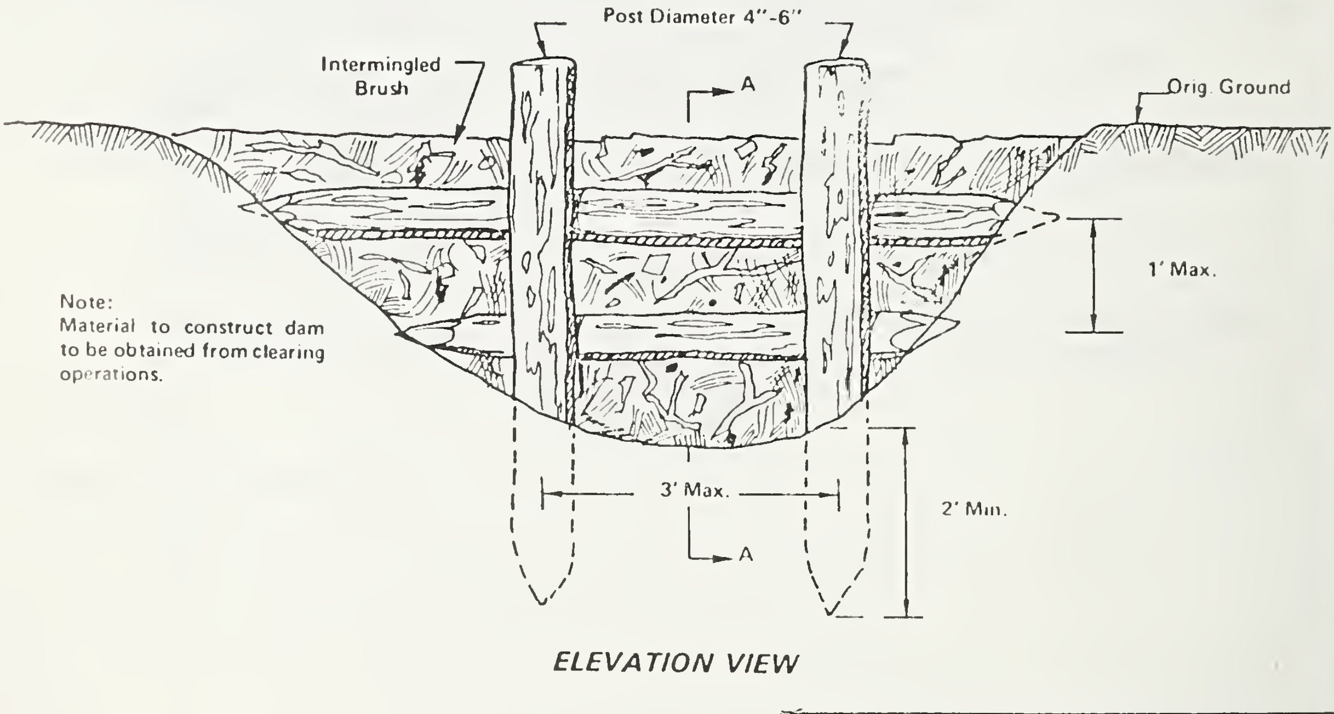
no scale

GABION CHECK DAM

Figure IV-1-A



SECTION A-A



ELEVATION VIEW

LOG AND BRUSH CHECK DAM

Figure IV-1-B

IV-2

DISCHARGE APRON AND ARMORED SCOUR HOLE

DEFINITION

A rock-lined apron at the discharge outlet of a drainage facility.

PURPOSE

To reduce the erosive energy and velocity of runoff at discharge outlets of drainage systems.

APPLICABILITY

To be used on the discharge outlet of all drainage facilities as required to prevent erosion.

PLANNING CRITERIA

Two energy dissipators in common usage are the armored scour hole and rock discharge apron.

Armored Scour Hole

- Design by a professional engineer is usually required.
- Configuration should be oval with the long axis parallel to the drainage discharge.
- The upper end of the scour hole should be eliptical (half of long axis = 9 feet minimum) and the lower end should be circular (4 feet radius minimum) in plan view.
- The hole should be armored to a minimum thickness of 0.75 times the diameter of the culvert with rock of which 50 percent is larger than 0.5 times the diameter of the cantilevered culvert over a gravel bed.
- Rock should be placed over a 9-inch layer of filter material as specified in BMP III-10.
- A typical plan section is shown in Figure IV-2-A.

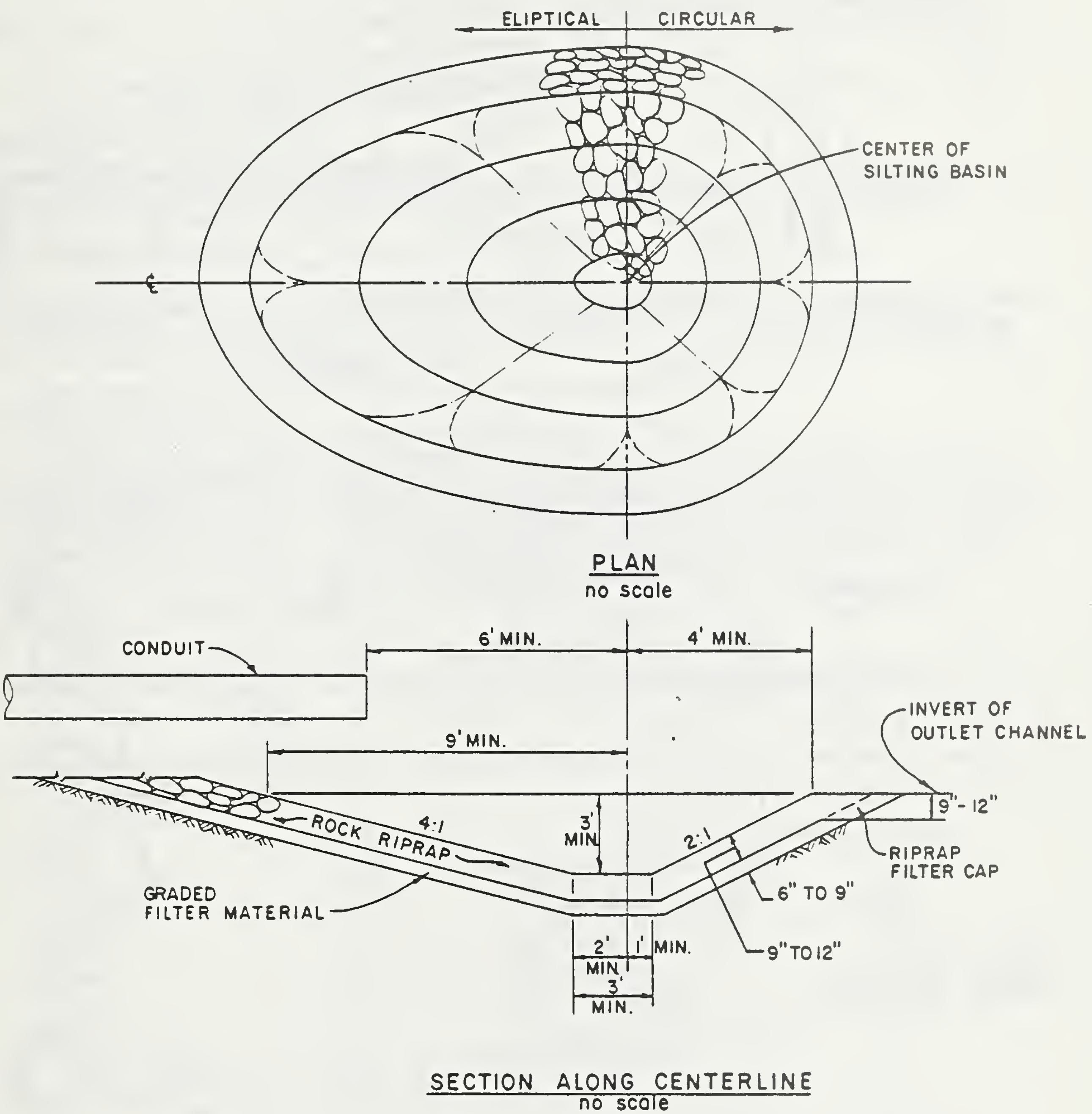
Rock Discharge Apron

- Formal design is not normally required.

- Configuration should be rectangular with minimum dimensions of all sides equal to four times the inlet pipe diameter.
- 50 percent of the rock should be larger than 0.5 times the culvert diameter.
- Rock should be placed over a 6-inch to 9-inch layer of filter materials as specified in BMP III-13.
- A typical section is shown in Figure IV-2-B.

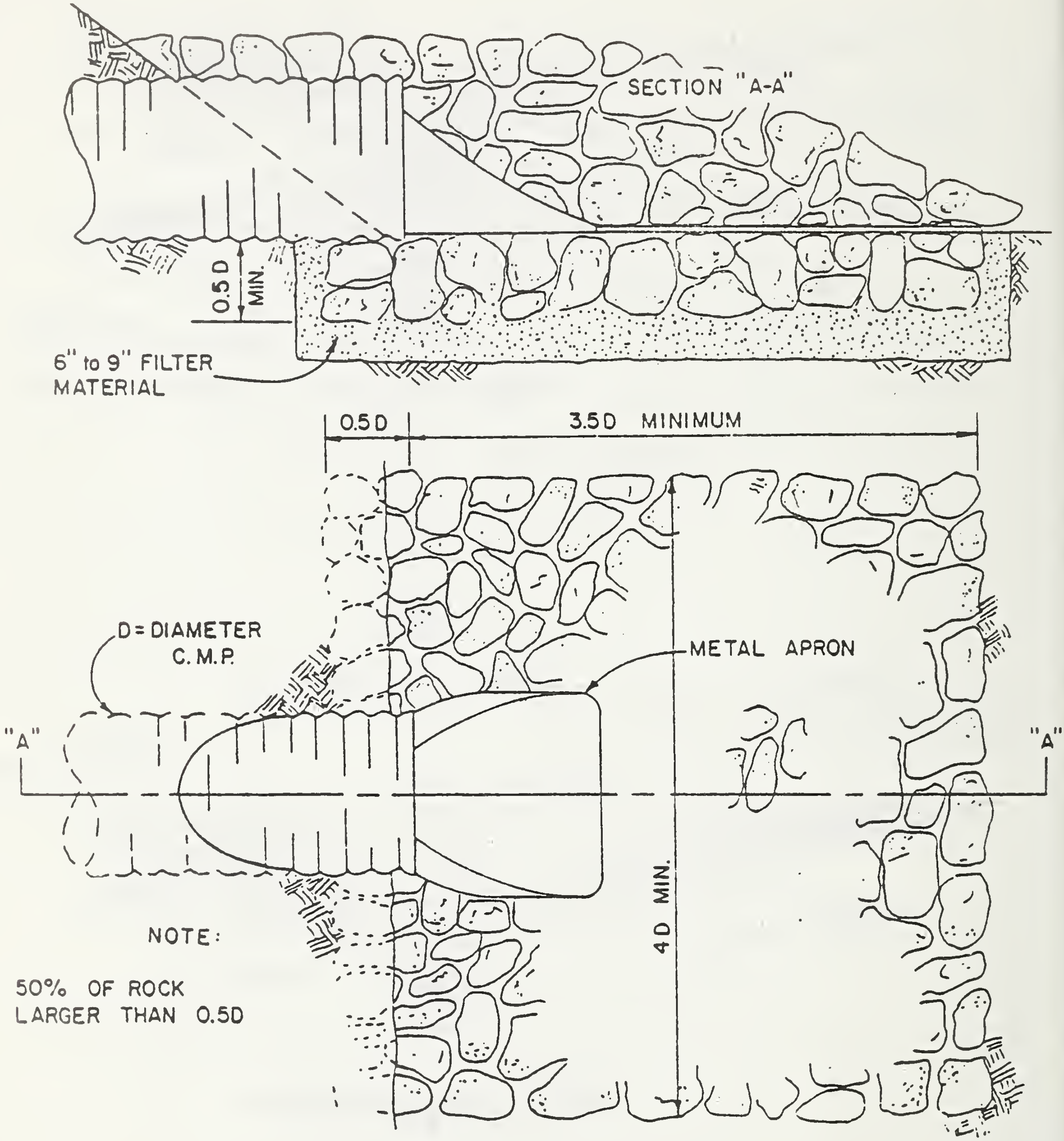
MAINTENANCE

Inspect for damage and repair periodically.



ARMORED SCOUR HOLE

Figure III-2-A



ROCK DISCHARGE APRON
Figure III-2-B

IV-3

DROP INLET

DEFINITION

A drop structure placed at drainage inlets to reduce flow velocities.

PURPOSE

To reduce erosion along inlet channels by reducing culvert discharge velocities.

APPLICABILITY

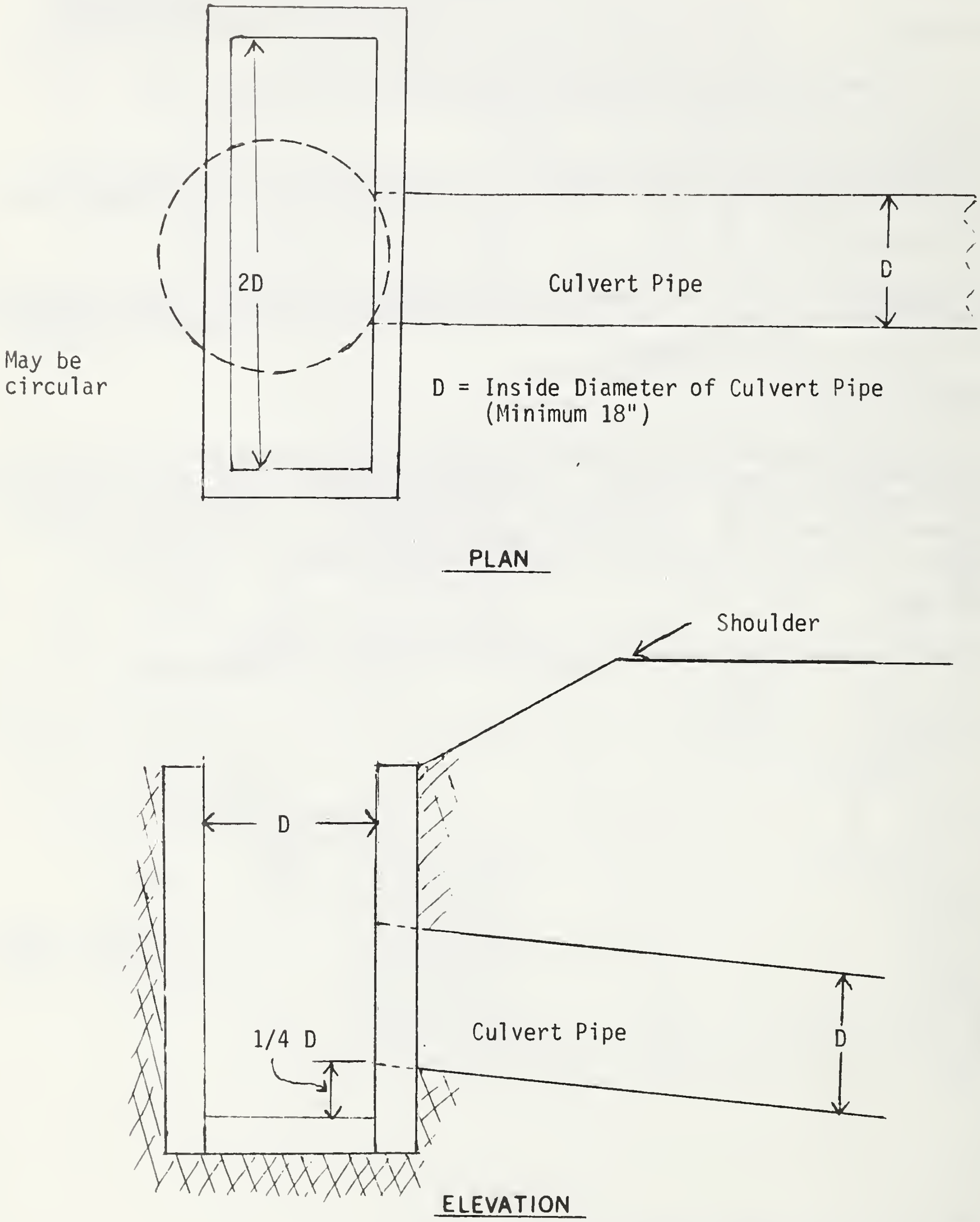
Drop inlets lower flow line gradients and provide energy dissipation at drainage inlets. They may serve as catch basins where water is collected from a flat area without a definite channel.

PLANNING CRITERIA

Drop inlets may be of masonry, prefabricated metal, concrete pipe or cast-in-place concrete. Precast concrete or prefabricated metal manholes can substitute for built-in structures. They may be either circular or rectangular in shape as shown in Figure IV-3. A culvert riser or debris barrier above the inlet may be necessary to trap sediments and alleviate clogging.

MAINTENANCE

Periodic cleaning and inspection after major storms may be necessary.



DROP INLET

Figure IV-3

IV-4

EROSION CHECK

DEFINITION

A porous, mat-like material installed perpendicular to the direction of flow in a ditch or channel.

PURPOSE

To prevent the formation of or to interrupt the growth of rills and gullies in drainage ditches and to provide grade control in such channels.

APPLICABILITY

Erosion checks have limited applicability in very minor drainage channels with flow velocities less than 2 feet per second and where erosion problems are not anticipated.

To be used with matting as specified in BMP IV-6.

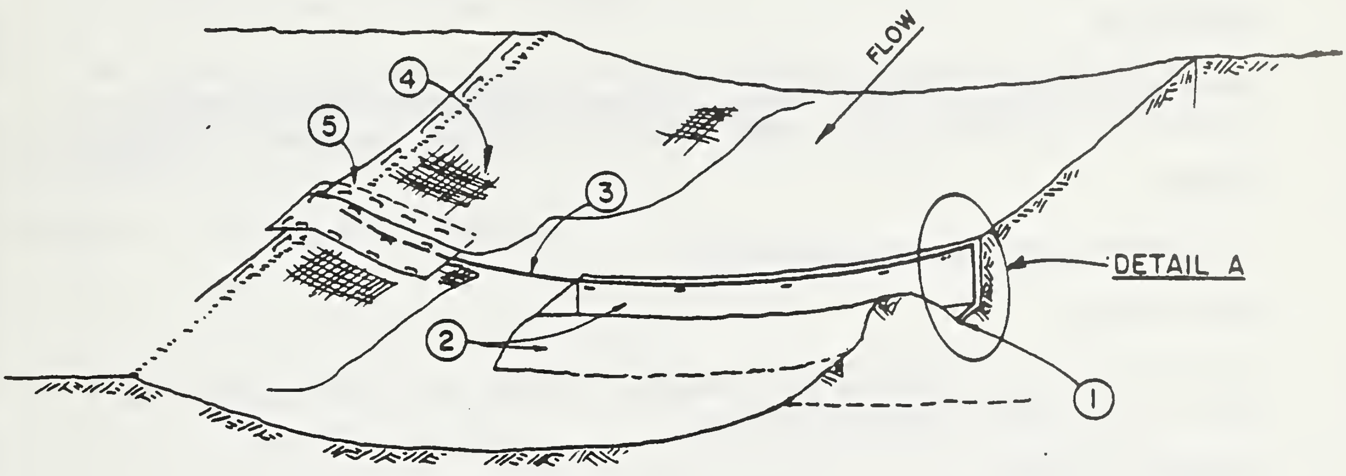
METHODS AND MATERIALS

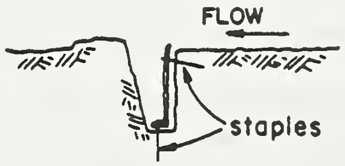
- Erosion checks should be constructed as shown in Figure IV-4.
- The material to be used for erosion checks should be flexible, porous, long-lived mats or membranes of fiberglass, plastic or jute.
- Erosion checks should be located at the following sites in a ditch or swale.
    - Immediately downstream from every tributary discharge point.
    - At each change in slope gradient.
    - Spaced regularly along the remainder of the channel at intervals determined using Appendix C.
- The bottom of the erosion check should be installed at least 3 inches below the maximum depth fo any existing rill or gully and 8 to 12 inches deep in newly graded areas.
- Erosion checks should be extended laterally at least 6 inches above the design flow elevation.
- Material should be stapled to the bottom of the trench and to the vertical face of the trench on 1-foot centers.

- The trench should be backfilled and compacted after installation of the erosion check. Material should be trimmed flush with the soil surface and the area should be reseeded where it has been disturbed by the installation.
- Erosion checks installed in drainage channels receiving new applications of matting should be covered with the channel matting as specified in BMP IV-5.
- A cap strip of mat or blanket material used in the establishment of vegetation in the drainage swale or ditch should be applied over erosion checks installed in drainage channels which have existing mat linings. The cap strip should extend a minimum of 2 feet on either side of the erosion check (upstream and downstream) and should overlap onto existing channel matting at least 1 inch. It should be stapled on 1-foot centers.
- The erosion check should be installed immediately after final grading and/or seedbed preparation.

MAINTENANCE

The erosion check should be inspected following each major storm and snow-melt event and repaired as necessary.





DETAIL A

(1) Installation in bottom of trench.

(2) Trench with spoil pile.

(3) Erosion check installed.

(4) Matting in drainageway

(5) Cap strip and completed erosion check

EROSION CHECK

Figure IV-4

CHANNEL PROTECTION - RIGID LININGS

DEFINITION

The use of riprap, grouted riprap, concrete, sacked concrete and asphaltic concrete for permanent soil stabilization in erodible drainage facilities.

PURPOSE

To stabilize open drainage channels.

APPLICABILITY

Rigid linings are preferred over mat-type linings where anticipated flow velocities exceed 2 feet per second.

PLANNING CRITERIA

- Open channels may be either lined or unlined subject to the following permitted velocities:

Channel Type	Permitted Velocity (ft/sec) Minimum	Maximum
Unlined Earthen Ditch	1	2
Riprap Lining	3	10
Grouted Riprap Lining	2	12
Asphalt or Concrete Lined	2	15
Vegetation	2	4

- Riprap has the advantage of adjusting to differential settlement along the channel while protecting against erosion. Riprap utilized for channel lining should consist of a well-graded layer about 1-1/2 times or more as thick as the dimensions of the largest rock fragments with a bulk specific gravity of not less than 2.5 minimum size for fines are those that are trapped by a 200-sieve. Rock fragments should be large enough to provide surface protection from erosion during the peak design flows. Riprap lining should be placed over a filter layer and extended to an elevation of at least 0.5 feet above the design waterline. The graded filter layer should be at least 6 inches thick with a gradation consistent with the base material and riprap. A typical channel section lined with riprap is shown in Figure IV-5.

- Grouted riprap, sacked concrete, gabions, concrete and asphaltic concrete permit maximum flow capacity due to their low roughness coefficients. They require a firm, compacted, stable foundation and must be carried below ground slope to prevent undercutting and at least 0.5 feet above the design waterline. Side slopes should not exceed 1:1.

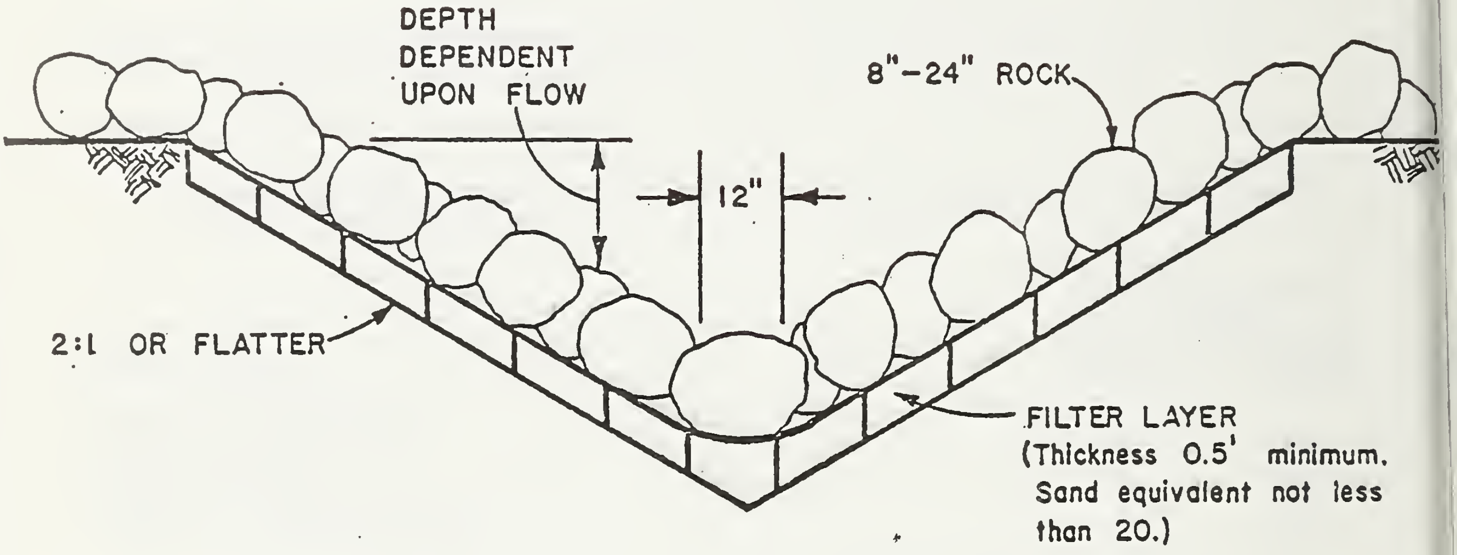
- Grade control measures may be required to reduce the gradient of open channels. Check dams, drop structures, erosion stops, or other structures should be located in a reasonably straight channel section; constructed

of durable materials adapted for use in hydraulic structures such as concrete, metal, rock, gabions or treated wood; and stabilized upstream and downstream at sufficient distances with riprap or other lining to prevent scour and bank erosion.

- Channel linings or other structures should be installed immediately after channel construction.

MAINTENANCE

Generally, no maintenance required.



TYPICAL SECTION
no scale

ROCK LINED CHANNEL
Figure IV-5

IV-6

CHANNEL PROTECTION-MATTING

DEFINITION

The use of jute, fiberglass roving or filter cloth as a soil stabilizing agent in erodible drainage facilities.

PURPOSE

To stabilize open drainage channels.

APPLICABILITY

This method has limited applicability in very small drainage channels with flow velocities less than 2 feet per second and where erosion problems are not anticipated. Matting should be used with seeding for permanent grassed waterways.

PLANNING CRITERIA

- Matting should be used only for intermittent streams which do not normally contain water other than during snowmelt or rainstorm runoff. Flow velocities should not exceed 2 feet per second.

- The drainageway should have a configuration which is amenable to this type of control. The optimum configuration is a low gradient, shallow, "U" shaped swale without physical instability. The material should be well compacted.

METHODS AND MATERIALS (See Figure IV-6)

- Site Preparation - Shape and grade the waterway, channel or area to be protected as required by job plans and specifications. Remove rocks, clods over 1-1/2 inches in diameter, sticks and other material that will prevent contact of the matting with the soil surface. Lime, fertilize mulch, and seed in accordance with the applicable seeding standard..

- Open channels lined with vegetation for erosion control should have sideslopes of 3:1 or less and a design flow velocity of 4 feet per second or less. Determination of hydraulic capacity should include evaluation of limitations imposed by mature vegetation.

- Placing the Matting - Apply the matting from the top of the channel or slope and continue downgrade.

    - When jute is used, one edge of the strip of neeting or matting should coincide with the channel center. Lay a second strip parallel to the first on the other side of the channel and allow at least a 4-inch overlap. If one roll of matting does not extend the length of the channel, continue downhill with additional rolls.

- Fiberglass roving should be laid continuously down the channel in a manner similar to that used on slopes.

- Securing the Matting - Bury the top end of the matting in a trench 8 inches deep. Backfill and compact the trench. Reinforce with a row of staples driven through the material about 4 inches downhill from the trench. These staples should be placed on 1-foot centers.

  - For jute, staple the overlap in the channel center with staples spaced 2 feet apart. The outside edges should be stapled similarly after the center has been stapled. Closer stapling along the sides is required where water may flow into the channel from the side (see Figure IV-6).

- Overlapping the Matting - Where one roll of matting ends and another roll beings, the end of the upper roll overlaps the trench where the upper end of the lower roll is buried. Make the overlap at least 3 feet and staple securely through both layers.

  - Roving should be tacked down with a tacking agent.

- Erosion Stops - May be installed at any point. Jute matting may be folded for burying in slit trenches and secured as were the upper ends. This checks water flow and erosion that may begin under the matting. It also gives improved tie-down. The procedure is recommended on the steeper slopes, sandy soil and slopes subject to seepage. See detail in Figure IV-6. Spacings should be determined as per Appendix C.

- Erosion Checks - May be substituted for erosion stops especially when used with fiberglass roving. See BMP IV-4.

- Tributary Inflows - The outlet should be protected with matting used in the same manner as in the main channel. The matting for the outlet is applied first and the matting in the main channel overlaps the outlet strip as shown in Figure IV-5.

- Matting Soil Contact - To achieve complete contact of the netting with the soil surface, the channel, lining should be rolled with a heavy roller after laying, stapling and seeding are complete. Complete contact is vital to keep water flow over - not under - the matting.

- Inspection - After the job completion, make sure the matting is in contact with the soil at all places and that critical areas are securely stapled.

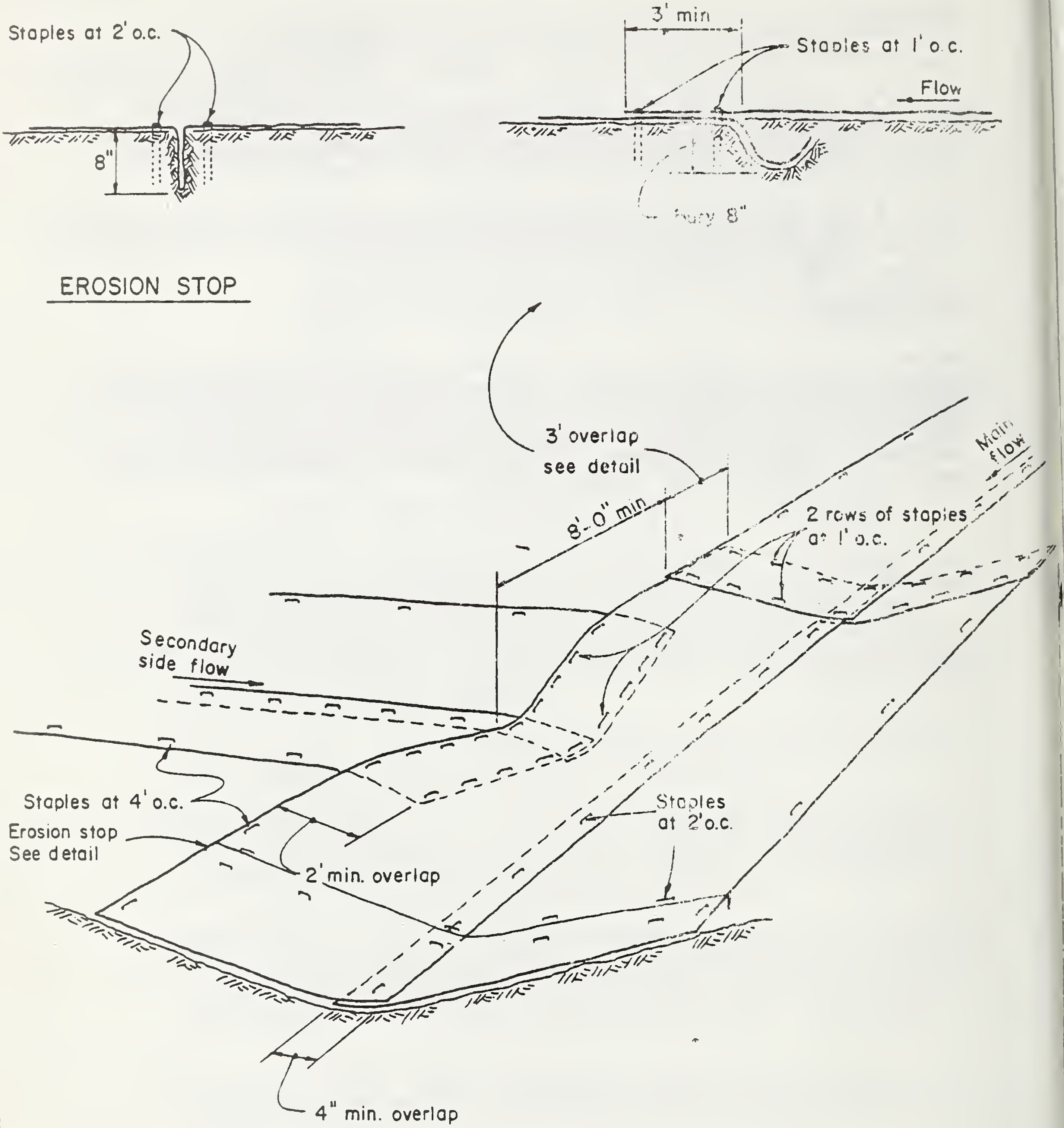
MAINTENANCE

Inspect following each major storm or snowmelt event and repair as necessary.

- If the grass has not become established, jute mat should be replaced, taking care not to disburb any areas of established grass.
- If vegetation has not been established, fiberglass lining should be replaced when it deteriorates to an extent that its soil stabilizing capacity is reduced.

EFFECTIVENESS

Values for matting installed in drainageways are variable due to several design and installation variables. Estimated sediment reductions of 50-90 percent can be expected for up to six months with jute. This effect declines to 20-60 percent in two years, and 10-30 percent after more than two years. Nutrient reductions of 30-70 percent, 10-50 percent and 0-10 percent are estimated for the same periods.



JUTE CHANNEL LINING

Figure IV-6

IV-7

LEVEL SPREADER

DEFINITION

An outlet constructed at zero grade across a slope to disperse concentrated runoff.

PURPOSE

To convert concentrated flow into sheet flow for outlet at nonerosive velocities onto areas stabilized by vegetation.

APPLICABILITY

Used at locations where concentrated runoff from unstabilized areas can be diverted onto stabilized areas under sheet flow conditions; e.g., at diversion dike or runoff interception trench outlets.

PLANNING CRITERIA

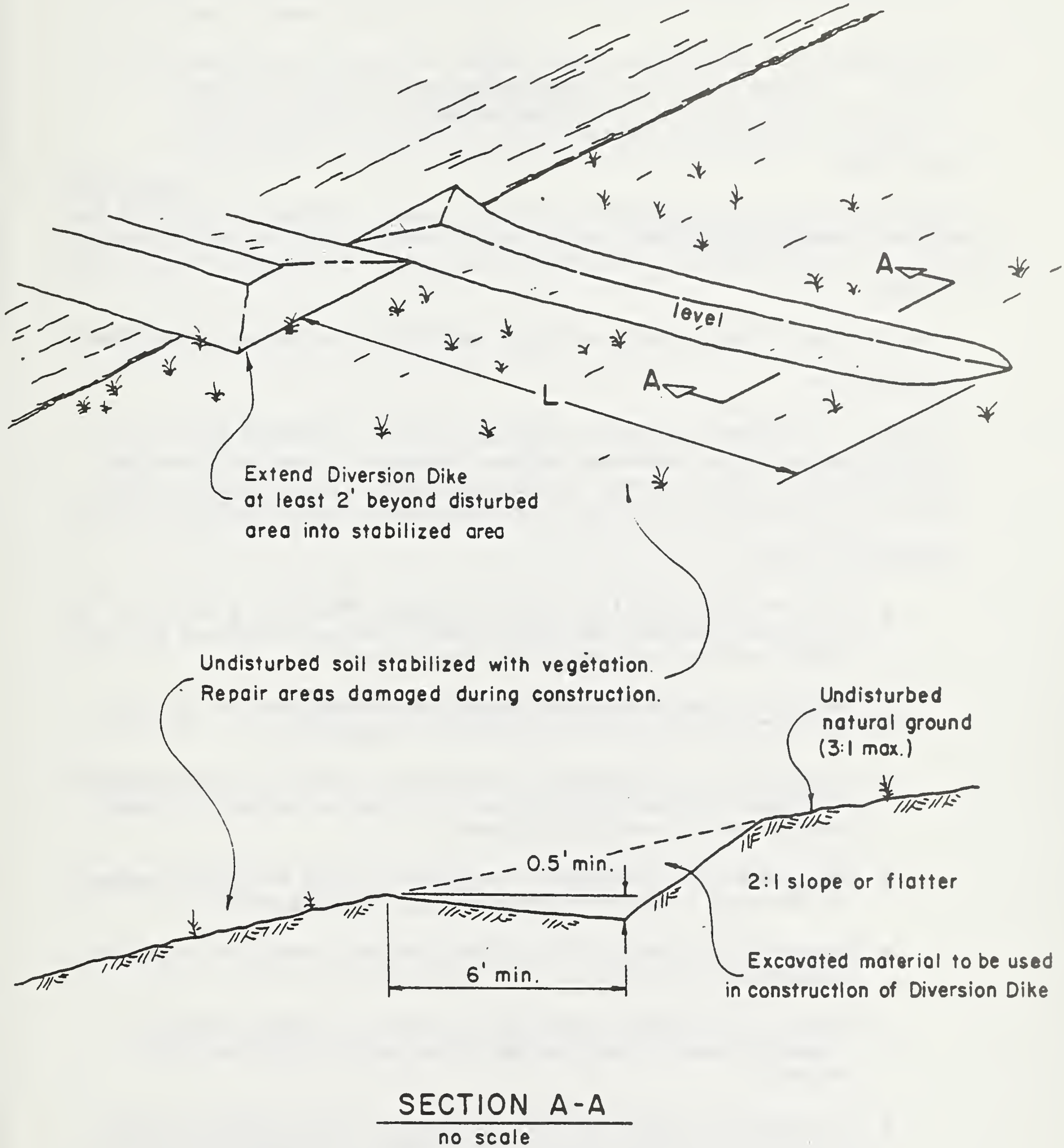
Detailed design is not required, but extreme care must be used during construction to ensure that the outlet lip is exactly level and uniform from end to end (IV-7). Failure to meet these requirements will cause concentrated flow and consequent erosion of the stabilized area. The excavation for the spreader must be on undisturbed soil (not cut or fill) and be well stabilized.

- Level spreaders should not be located on slopes steeper than 3:1.
- General criteria include:
    - Depth Below Level Lip - At least 0.5 feet.
    - Length - 15 lineal feet minimum for each 0.1 cfs of discharge.
    - Width - At least 6 feet from centerline to level lip.
    - Back Slope - 2:1 or flatter.
    - Material - Should be constructed in undisturbed soil and should outlet into a stabilized area.
    - Inflow - Runoff to the spreader should be from areas which have been stabilized to eliminate sediment buildup in the spreader.

- Discharge - When discharge is to a slope steeper than 4:1 or the soil is highly erodible, the length of the spreader should be increased and slope stabilization methods as shown in BMP Chapter I should be installed on the discharge lip to ensure the stability of the discharge area.

MAINTENANCE

Inspect for damage after each storm. Repair as required. Remove sediment as necessary.



LEVEL SPREADER

Figure IV-7

IV-8

SLOPE SERRATION
(SCARIFYING)

DEFINITION

The construction of approximately 10-inch square, horizontal steps on the entire face of a cut slope.

PURPOSE

To provide stabilized benches on which vegetation can become established.

APPLICABILITY

Serration is limited to slopes in medium to highly cohesive soils or in soft rock which can be excavated without ripping. Slope angle must be gentle enough to permit access to heavy equipment (2:1 or less). The method is not applicable for use in moraines and other depositional soils.

PLANNING CRITERIA

- A dozer, equipped with a special blade containing a series of 10-inch square grooves and positioned at the same angle as the cut, should serrate the slope along the contours.
- Serrations should be approximately horizontal but may parallel the roadway grade if it is less than 2 percent.
- Excavation of each series of serrations should be in the opposite direciton from the preceding one to minimize buildup of loose material at the ends of the steps.
- Loose material collected at the ends of steps should be removed and the ends blended into the natural ground surface.
- Where rock too hard to rip is encountered, serrations should be blended into the rock.
- Materials which fall into the ditchline or roadway and rock fragments greater than one-third the shelf width should be removed.
- Serration of slopes composed of material that weathers rapidly should be completed early in the summer to allow sloughing of material off the step face prior to fall revegetation to prevent smothering seed or seedlings.

- A slope bench should be constructed at the bottom of the slope face as shown in BMP V-9.

- Revegetation should be accomplished within 7 days following slope serration using appropriate methods from BMP Chapter II. In decomposing material which sloughs readily, revegetation should be delayed until at least 30 days following the slope serration.

MAINTENANCE

Inspect periodically for damage from surface runoff and seepage. Revegetation should be accomplished as required on serrated slopes with excessive sloughing.

IV-9

SLOPE STEPPING

DEFINITION

The construction of a continuous series of horizontal steps on the face of cut slopes.

PURPOSE

To reduce uninterrupted slope length and provide slope stabilization.

APPLICABILITY

Used in new construction on cut slopes in soft rock which can be excavated by ripping.

Slope stepping is not practical in cuts with soft rock laminations in thin layers oriented so that the strike is approximately parallel to the slope face and the dip approximates the staked slope line. Slope steps are larger than slope serrations and are used on larger slopes.

PLANNING CRITERIA

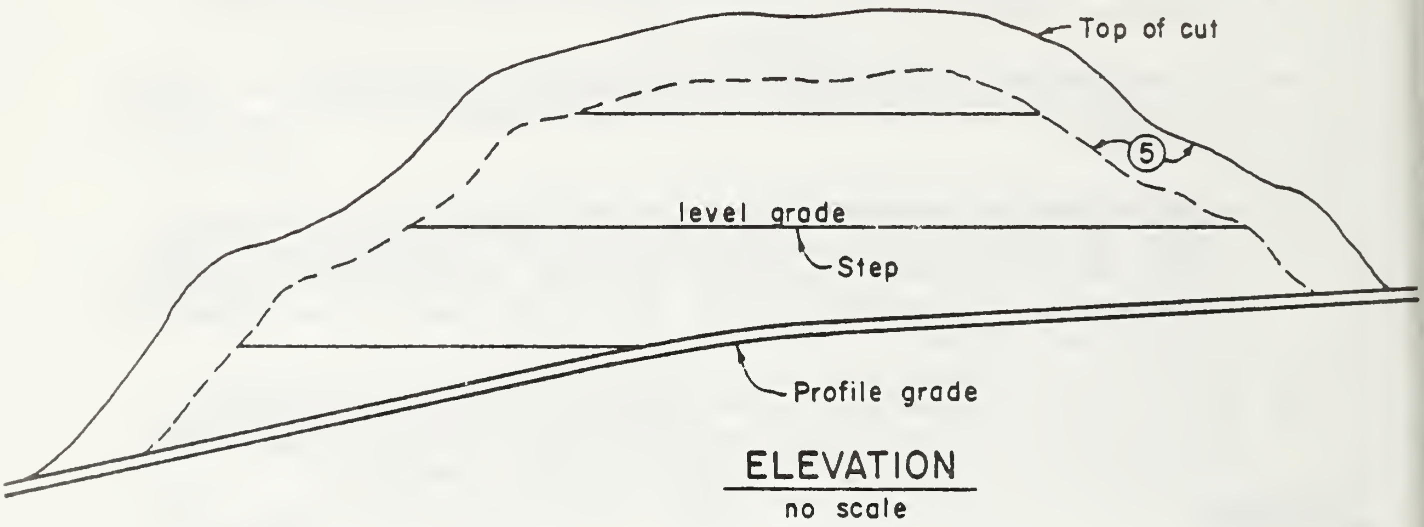
Slope stepping should be used to reduce the uninterrupted slope face length. Slopes should conform to guidelines in Appendix C.

- Cuts in soft rock should be excavated in a stepped pattern as shown in Figure IV-9.
- The steps may vary from 2 to 4 feet vertically. The horizontal dimensions should be equal to the slope ratio times the step-rise height.
- The upper step should begin immediately below the soft-rock line and continue to the bottom of the slope.
- Steps should be approximately horizontal but may parallel the roadway grade if it is less than 2 percent.
- Steps should have approximately vertical back slopes.
- Excavation of each step should be in the opposite direction from the preceding one to minimize buildup of loose material at the ends of steps.

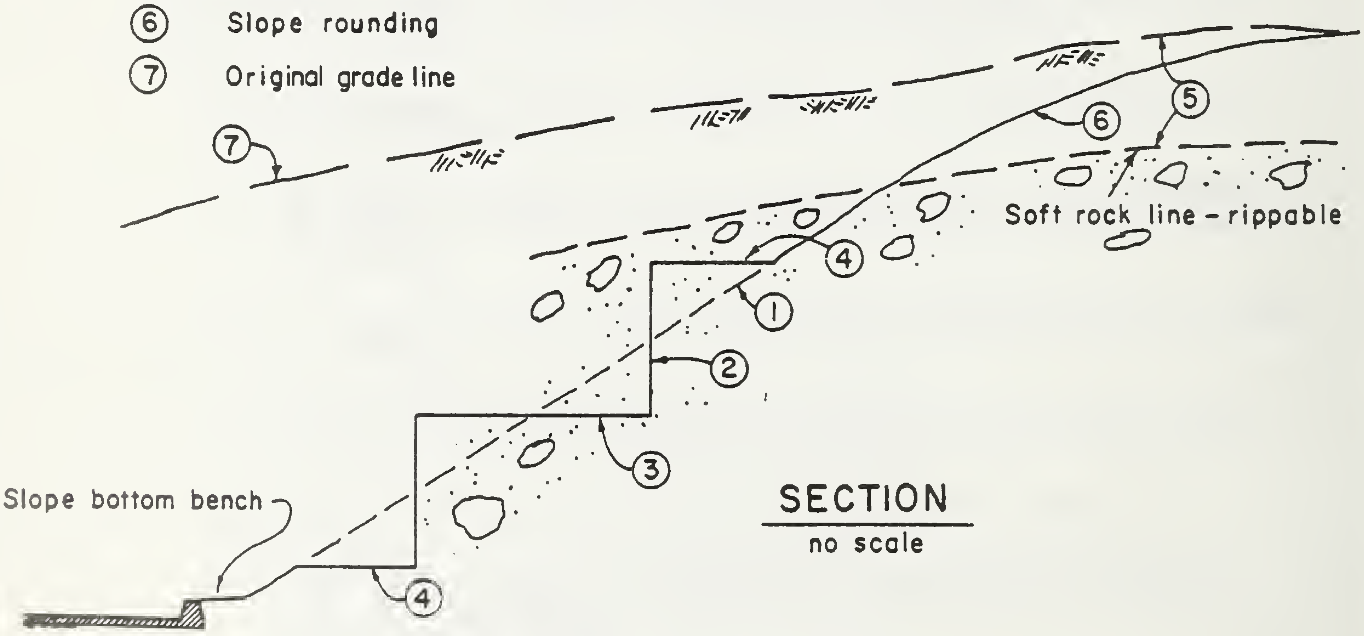
- Loose material which collects at the end of steps should be removed and the ends blended into the natural ground surface.
- Where rock too hard to rip is encountered within a cut, the steps should be blended into the rock.
- Scaling need not be performed on the stepped slopes except for removal of rock fragments larger than material which may fall into the ditchline or roadway.
- Slopes should be revegetated with the appropriate methods from BMP Chapter II immediately following completion of construction of final grade. Sufficient funds should be allocated to provide for substantial maintenance of revegetation for at least three years following the first revegetation attempts.
- Construction of downdrains may be required to convey surface runoff from the steps to the base of the slope without erosion. This should be determined by an analysis of the local site conditions.

MAINTENANCE

Inspect periodically for damage. Excessive surface runoff or seepage should be controlled with appropriate drainage facilities. Damaged areas should be revegetated immediately.



1. Staked slope line
2. Steprise height 2 - 4 feet
3. Step tread width = Slope ratio x steprise
4. Step termini width = 1/2 step tread
5. Overburden
6. Slope rounding
7. Original grade line



SLOPE STEPPING

Figure IV-9

CHAPTER V

SEDIMENT COLLECTION

Contents and Applicability

BEST MANAGEMENT PRACTICES (BMP):

V-1 TEMPORARY BARRIER-STRAW BALES. To be used where temporary diversions or berms are required. The straw allows water to filter through and retains sediments. Daily inspection is necessary.

V-2 TEMPORARY BARRIER-SANDBAGS. Similar to straw bale sediment barriers, but no filtration of runoff water is achieved. Used to divert or otherwise control stormwater runoff.

V-3 CULVERT RISER. Vertical pipe attachment to culvert inlet where inlet is located in depressed area that can serve as a sediment trap. As water level rises, sediment settles from the top of the pool and only clear water enters the culvert riser.

V-4 FILTER BERM. Gravel berms used to remove sediments from runoff water.

V-5 FILTER FENCE (SILTFENCE). A barrier constructed of filter cloth and used to provide sediment removal from runoff water discharged from a site.

V-6 FILTER INLET. A temporary berm used at a storm sewer inlet during construction. It retains sediments while allowing storm flows to pass.

V-7 SEDIMENT RETENTION OR FLOW DETENTION BASIN. Basins or dams for capturing sediment materials and providing flow detention in runoff from construction sites or in permanent storm drainage systems.

V-8 SEDIMENT TRAP. Small storage or detention areas for capturing sediment in runoff from construction site. Generally used for drainage areas of 10 acres or less.

V-9 SLOPE BOTTOM BENCH. A sediment retention device to be used at the base of small oversteepened slopes which cannot be regraded due to easement or other restrictions.

V-10 VEGETATIVE BUFFER STRIP. Area of vegetation through which runoff must flow before entering drainageways. As the water containing suspended sediment flows through the strip, some is removed by filtering and by deposition as flow velocity is reduced.

V-11 FLOATING SEDIMENT BARRIER (DIAPER). Plastic or impermeable barrier suspended in a waterway to contain sediment.

V-12 COFFERDAM. Structure of steel, rock or wood constructed in waterway to enclose work area and prevent sediment and debris movement into downstream areas.

V-1

STRAW BALE SEDIMENT BARRIER

DEFINITION

Temporary berms, diversions, or other barriers constructed of baled straw.

PURPOSE

Straw bale sediment barriers retain sediment on site by retarding and filtering storm runoff.

APPLICABILITY

The barriers are used at storm drain inlets, across minor swales and ditches, as training dikes and berms, along property lines, and for other applications where the structure is of a temporary nature and structural strength is not required.

PLANNING CRITERIA

The following information applies to the installation of straw bale sediment barriers (See Figures V-1-A and V-1-B).

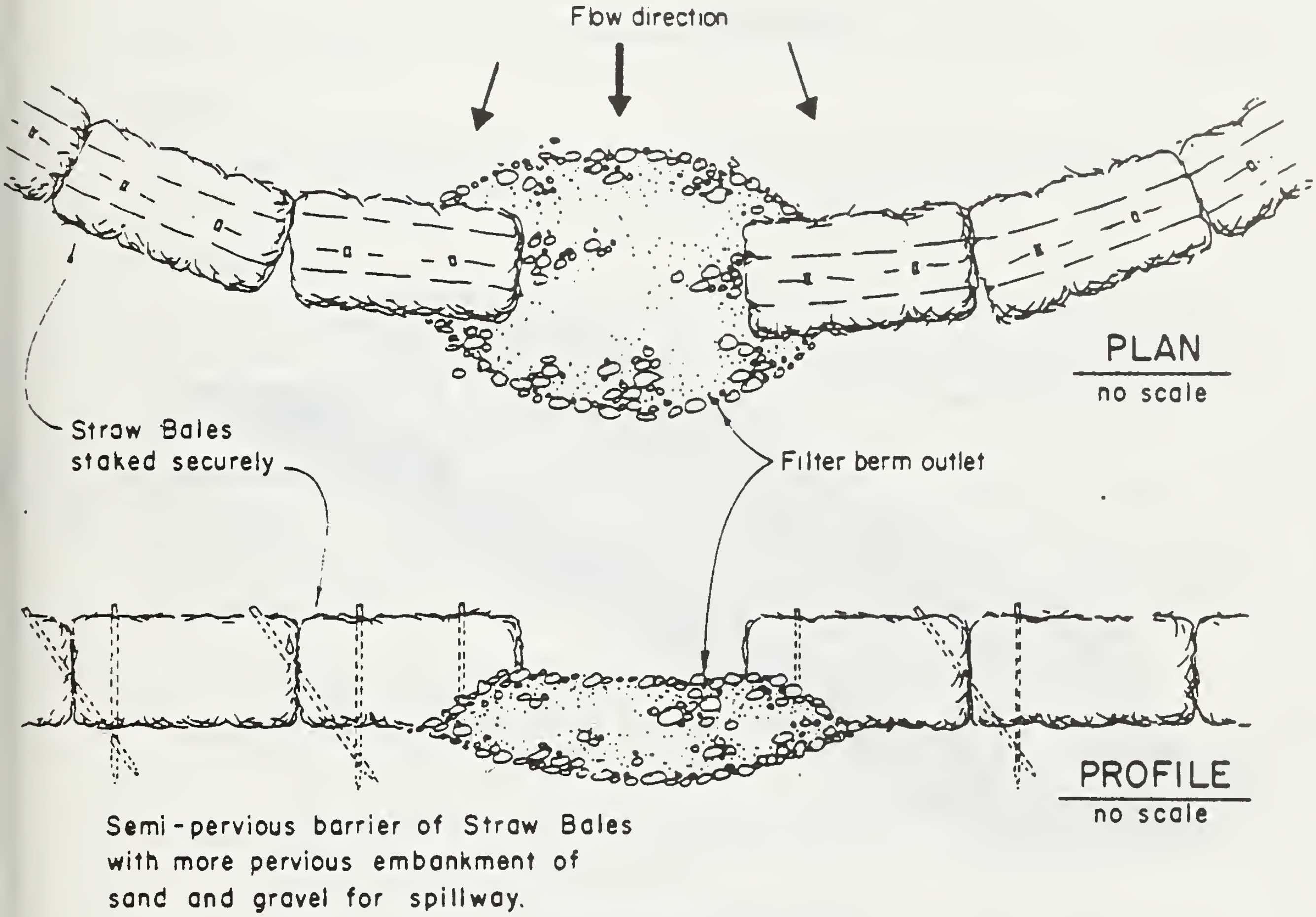
- The service life of the barrier can be prolonged by using wire- or nylon-tied rather than those tied with twine.

- Bales should be laid on their sides and staked in place. At least two wooden or metal stakes should be driven through each bale and into the ground at least one foot. The first stake should be angled toward the previously placed bale and driven through both the first and second bale.

- Piping is a major cause of failure. The possibility of piping failure can be reduced by setting the straw bales in a trench excavated to a depth of at least 15 centimeters (6 inches) and by firmly tamping soil along the upstream face of the barrier.

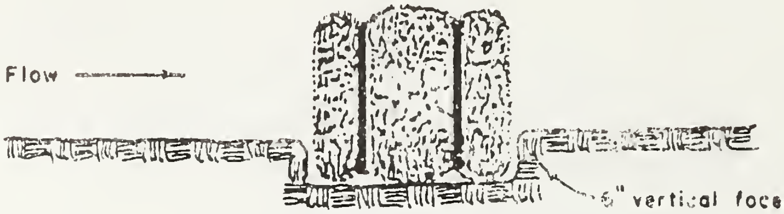
MAINTENANCE

Bales are a target for vandals and frequent inspection may be required. They should be replaced when rotten or disintegrating. Remove deposited sediment from bale structures after each storm.

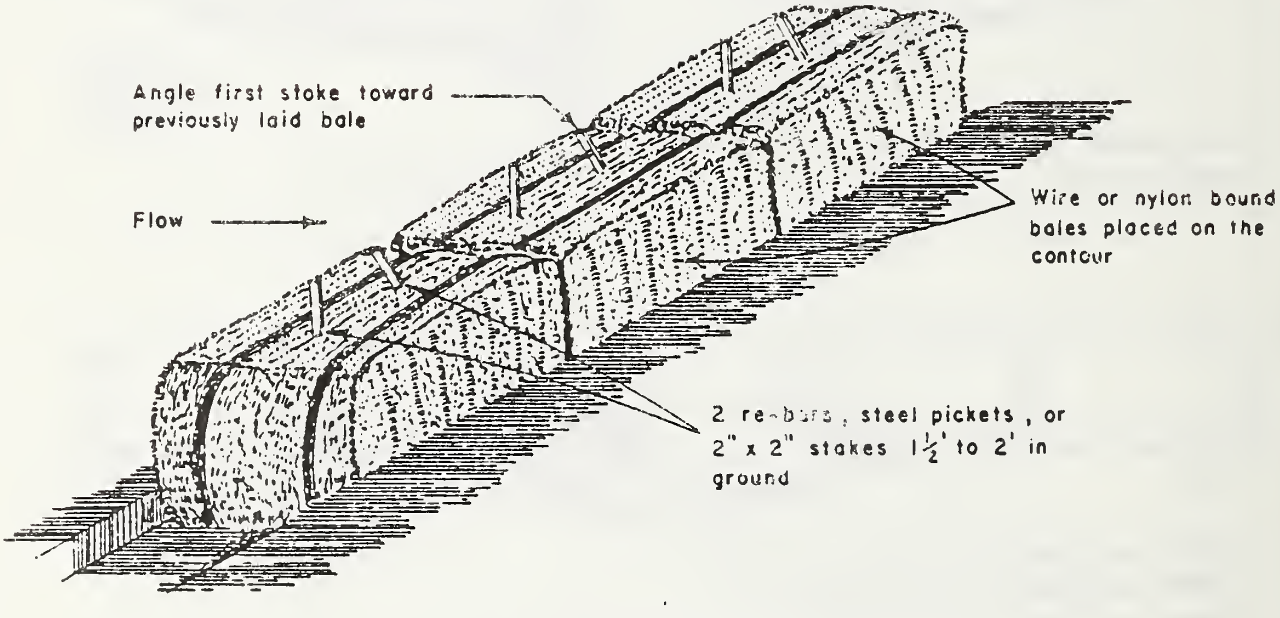


STRAW BALE BARRIERS

Figure V-1-A



EMBEDDING DETAIL



ANCHORING DETAIL

STRAW BALE SEDIMENT BARRIER
V-1-B

V-2

SANDBAG SEDIMENT BARRIER

DEFINITION

Temporary sediment barriers or diversions that are constructed of sandbags.

PURPOSE

The barriers are built to retain sediment on site by slowing storm runoff and causing the deposition of sediment at the structure.

APPLICABILITY

Sandbag sediment barriers are used at storm drain inlets, across minor swales and ditches, and for other applications where the structure is of a temporary nature. Sandbag barriers do not provide filtration. They therefore can be used only for minor flows.

PLANNING CRITERIA

Sandbag sediment barriers are used as training berms to direct or divert runoff flows, or as barriers to collect and store runoff. The following information pertains to the installation of sandbag sediment barriers.

- Install so that flow under or between bags is prevented.
- The sandbags should be stacked in an interlocking fashion to provide additional strength for resisting the force of the flowing water.
- Sandbags should not be stacked more than three high without broadening the foundation using additional sandbags, or providing additional stability.
- Sandbag sediment barriers should store the runoff from design storm as specified.

MAINTENANCE

Inspect after every storm and replace damaged bags. Clean out trapped sediment after each storm.

CULVERT RISER

DEFINITION

Perforated metal pipe attached to culvert inlet and extending upward.

PURPOSE

Culvert risers permit inlet areas of culverts to serve as temporary or permanent sediment traps in the same manner as sediment detention basins.

APPLICABILITY

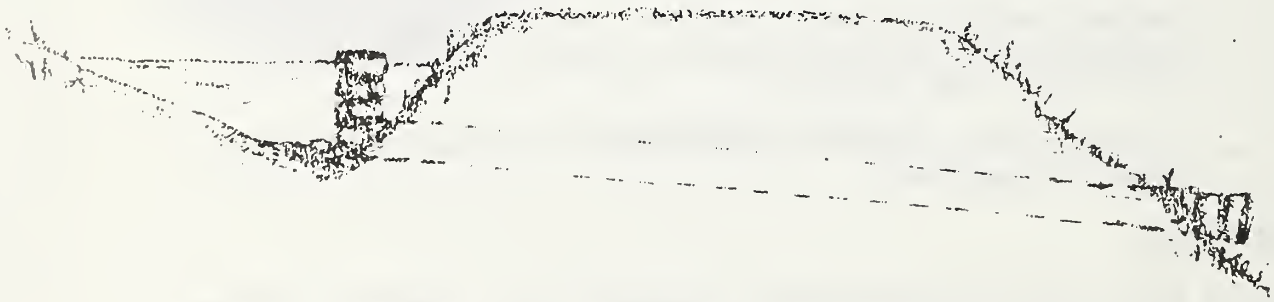
Risers are used at culvert inlets which receive runoff from upstream construction sites. As water pools up behind the culvert embankment, sediment settles out.

PLANNING CRITERIA

Proper riser design should be based upon the total drainage area lying upstream. See criteria used for sediment basins - BMP V-8.

MAINTENANCE

Risers should be inspected and cleaned of deposited sediment periodically and following storms. Sediment should be disposed of where it is not likely to reenter flow of runoff.



CULVERT RISER
Figure V-3

V-4

FILTER BERM

DEFINITION

A filter berm is a temporary ridge of gravel or crushed rock.

PURPOSE

To retain sediment on-site by retarding and filtering runoff while allowing water to be discharged from the site.

APPLICABILITY

Filter berms may be used as outlets for sediment barriers around construction sites, where graded areas meet paved roadways, in uncompleted drainage facilities, or any other location requiring detention and filtration of runoff water.

PLANNING CRITERIA

Filter berms are used to filter runoff water for discharge from the site. Continuous filter berms may be used around construction sites or individual berms may be located at discharge points in impermeable barriers.

- If continuous filter berms are used, discharge through should be to a stable area such that no erosion occurs.

- Detailed design is not required. Figure III-7 provides general design criteria. Minimum requirements for use on graded rights-of-way are as follows:

Height:	1.5' to 3'
Top Width:	3' to 5'
Side Slopes:	3:1 or flatter
Material:	Coarse (3/4" to 1½"), well-graded gravel or crushed rock. Fines less than 5%.
Filter Cloth:	As specified in BMP V-5.

MAINTENANCE

Remove all trapped sediment and clean out or replace clogged filter material after each storm. Repair as damaged by traffic.

V-5

FILTER FENCE
(SILTFENCE)

DEFINITION

A low fence made of filter cloth and fencing material.

PURPOSE

To filter runoff water prior to discharge.

APPLICABILITY

Any construction site or other site of disturbance where the danger of discharge of sediment-laden water exists.

PLANNING CRITERIA

A filter fence can be substituted for a filter berm at approximately equal cost, but the filter fence is easier to maintain and remove. Care must be taken to insure that all runoff water must pass through, not over, under or around, the filter cloth. This only applies to sites which will not be subjected to significant hydrostatic pressure or to vehicular traffic.

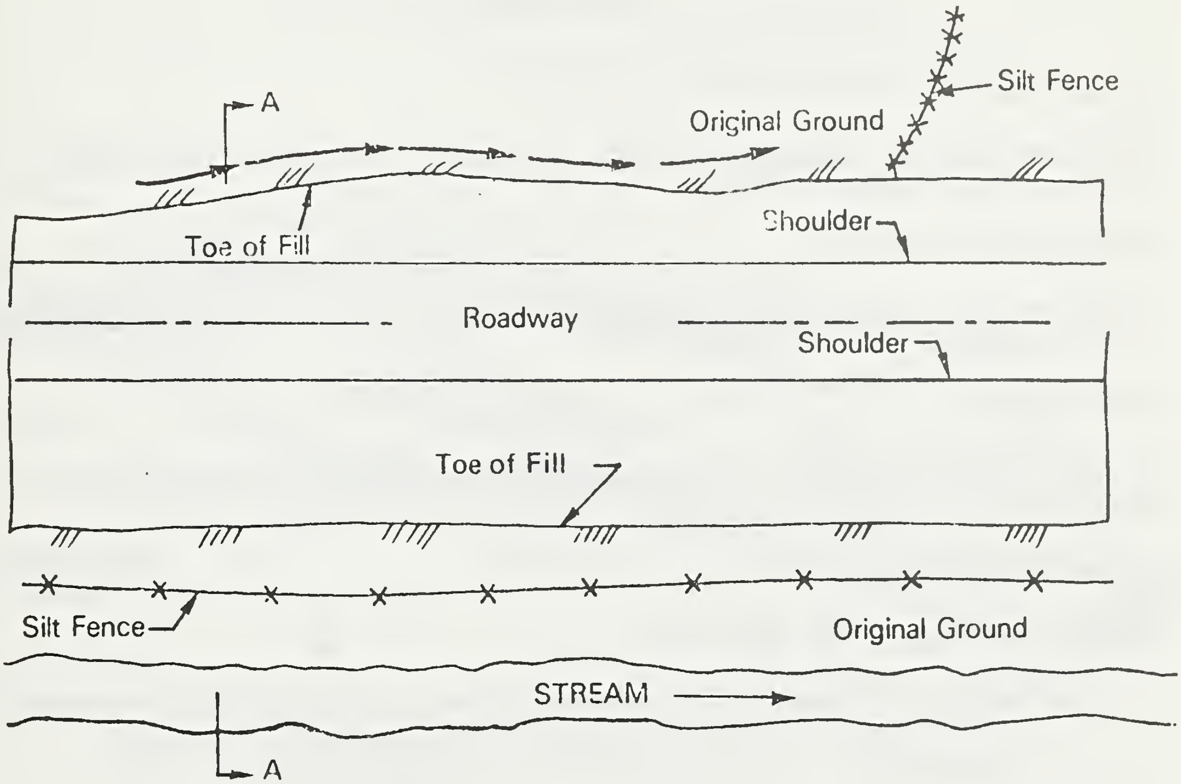
METHODS AND MATERIALS

- The filter fence to be used during the period from May 1 to October 15 should be designed to filter the design storm without overtopping, collapsing, becoming sedimented in, or being skirted by runoff flows.
- The fence should be constructed with "T" -section fench posts and "hog-wire" (4"x4" or 6"x6" wire mesh) or "chicken-wire" of #14 or heavier gauge wire. The fence should be constructed as shown in Figure V-5.
- A trench should be excavated at the uphill base of the fence to a depth of at least 6 inches.
- Filter cloth (Mirafi 140 or equivalent) should be draped over the wire fencing material and lowered into the trench.
- The trench should be backfilled to grade and compacted.

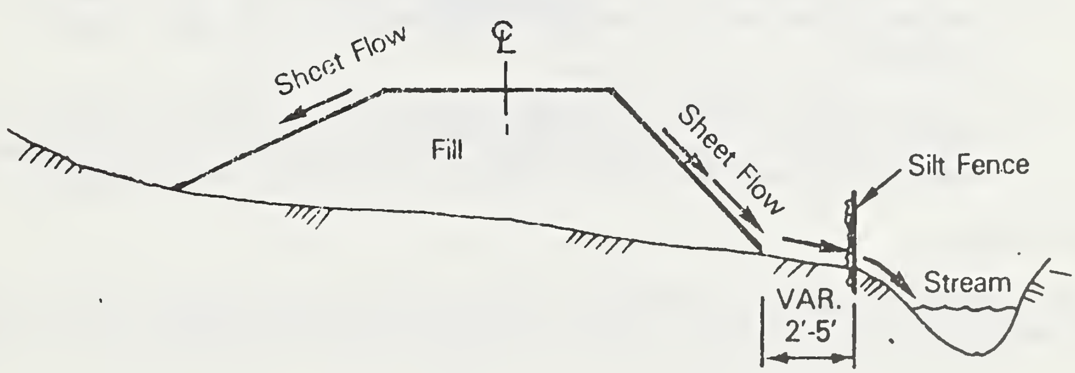
MAINTENANCE

Inspect periodically and after each storm for damage and repair or replace damaged sections. Remove sediment accumulations when the capacity of the filter is impaired.

TYPICAL CONDITIONS WHERE SILT FENCES ARE APPLICABLE



PLAN VIEW



SILT FENCE

Figure V-5

V-6

FILTER INLET

DEFINITION

A filter inlet is a temporary filter of gravel or crushed rock placed at storm drain inlets.

PURPOSE

Filter inlets retain sediment from runoff water prior to discharge into storm drains.

APPLICABILITY

Filter inlets are used at storm drain inlets which receive runoff from upstream construction sites.

PLANNING CRITERIA

Specific design is not required.

- Several different design concepts are in use and the configuration of the gravel inlet will depend on the type of inlet being protected.

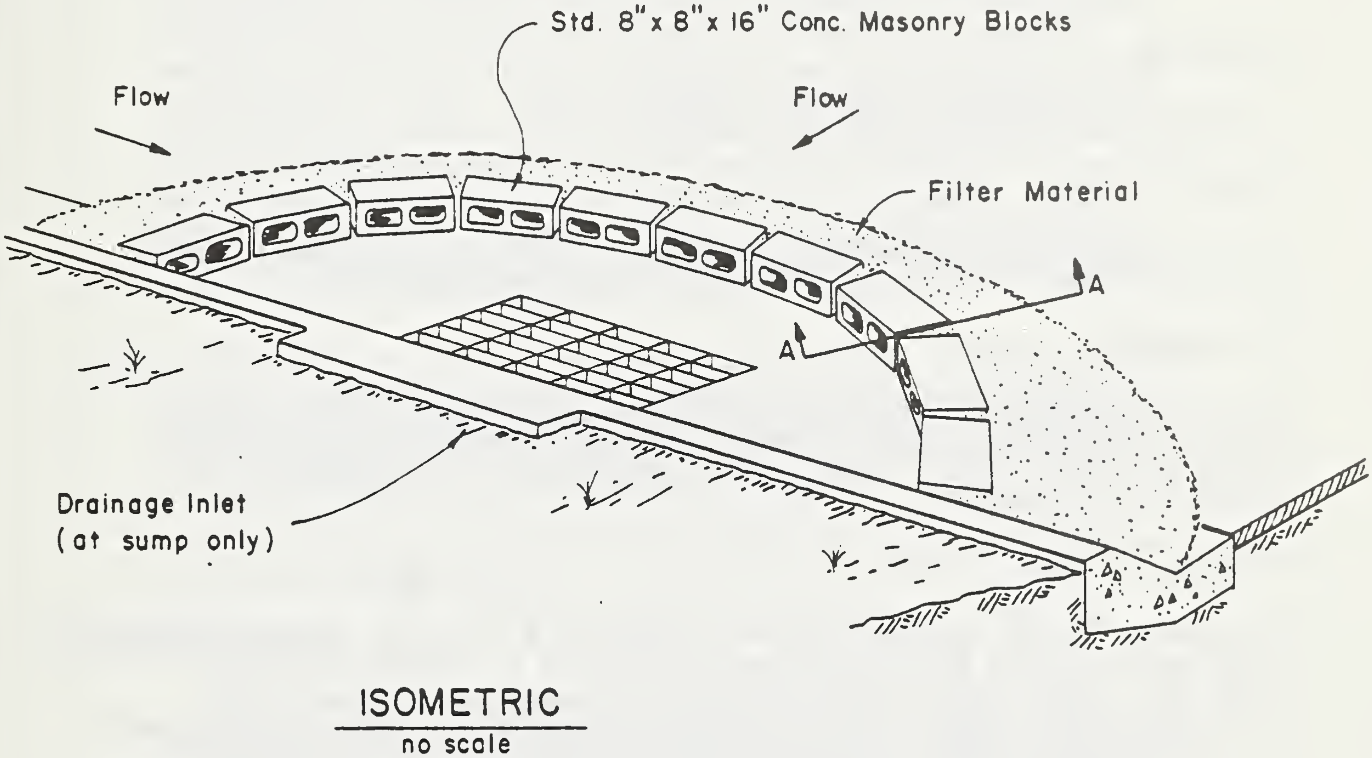
  - The design uses a filter berm as shown in Figure V-6 around the inlet structure. Alternatives utilize concrete building blocks to keep berm material from entering the storm sewer.

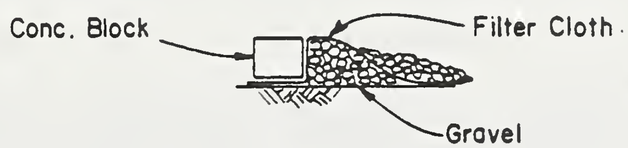
- All filter material should be coarse (3/4" to 1-1/2"), well-graded gravel or crushed rock. Fines should be less than 5 percent.

- Filter cloth should be placed inside the filter bed as shown in Figure V-6. Enough aggregate must be used to insure complete contact between the filter cloth and the underlying surface.

MAINTENANCE

Remove trapped sediment after each storm and replace clogged filter material as needed.





SECTION 'A-A'

FILTER INLET

Figure V-6

SEDIMENT RETENTION OR FLOW DETENTION BASIN

DEFINITION

A temporary or permanent dam or basin.

PURPOSE

Used to trap and store sediment contained in surface runoff and to serve as a flow detention facility for reduction of peak runoff rates.

APPLICABILITY

Small temporary structures can be used to trap sediment in runoff from construction sites. Larger permanent structures can provide substantial reduction of peak runoff rates when incorporated into the design of a storm drainage system.

PLANNING CRITERIA

The example design presented below is applicable for small sediment basins. Large basins should be designed and constructed to conform to Idaho state law. This design applies primarily to areas where land grading operations are planned or are underway and is used as a temporary measure until areas above the installation are permanently protected against erosion by vegetative or mechanical means or as a permanent sturcture for small drainage basins. The structure may become part of the permanent drainage system for the area following completion of construction.

Sediment basins covered by this standard should be limited to the following category:

> The water surface at the crest elevation of the pipe spillway should not exceed nine feet (9') measured upward from the original streambed to the crest elevation of the pipe spillway; and the drainage area should not exceed 150 acres.

Design

- See Figure V-7. Design of the basin should be based upon the total drainage area lying upstream and if permanent on the future use of such lands and should be completed by a professional engineer.

- Vegetation should be planted on all embankment slopes, borrow areas, or any other areas disturbed during construction.

Storage

- The site should be selected to provide adequate storage for not less than 0.5 inches of runoff per acre of drainage area. Runoff calculations should be as specified in Appendix A. Volume for trap efficiency calculations should be the volume below the emergency spillway crest or pipe spillway crest, if there is no emergency spillway. When necessary, consideration should be given either to excavating additional storage capacity to meet these requirements or to plan for periodic cleanout in order to maintain the capacity requirements. Where available sites do not lend themselves to meeting such design criteria, approval should be obtained from the permit-issuing authority to design and install a sediment basin with less storage.

- Sediment basins should be cleaned out when the effective storage capacity drops below 0.2 inch of runoff per acre of drainage area. The elevation corresponding to this level should be determined and given in the design data as a distance below the top of the riser.

- Storage should be designed not to produce a public nuisance as an insect breeding site.

Runoff Computations

- Combined capacity of the pipe and emergency spillways should be designed to handle a 50-year frequency storm. Runoff should be calculated by the method contained in Appendix A and should be based on soil cover conditions expected to prevail during the anticipated effective life of the structure.

Pipe Spillways

- Design the pipe spillway to handle not less than 5 inches runoff from the drainage area for 24 hours. The pipe spillway will consist of a perforated vertical pipe or box-type riser joined to a horizontal conduit (barrel) which will extend through the embankment. The horizontal pipe conduit (barrel) should be a minimum of 12 inches in diameter. The riser should be a minimum of 30 inches in diameter with a cross-sectional area of at least 1.5 times the cross-sectional area of the horizontal conduit.

  - Crest Elevation - When used in combination with emergency spillways, the crest elevation of the riser should be at least one foot below the elevation of the control section of the emergency spillway. If no emergency spillway is provided, the crest elevation of the riser should be at least three feet below the crest elevation of the embankment.

- Perforated Riser - The upper portion of the riser should be perforated with 1-1/2 to 4 inch diameter holes spaced 8 inches vertically and 10 to 12 inches horizontally and staggered. The preforated portion should be the top one-half to two-thirds of the riser. The whole pipe length should be perforated if a gravel filter cone is placed around the bottom one-third of the riser. Perforations should be small enough to not allow the passage of filter material.

- Antivortex Device - An antivortex device should be installed on the top of the riser. An approved antivortex device is a thin, vertical plate normal to the centerline of the dam and firmly attached to the top of the riser. The plate dimensions are: length = diameter of the horizontal pipe.

- Base - The riser should have a base attached with a watertight connection and should have sufficient weight to prevent floatation of the riser. Two approved bases are:
  (1) A concrete base 18 inches thick with the riser imbedded 6 inches in the base. The base should be square with each dimension 2 feet greater than the riser diameter.
  (2) A 1/4 inch minimum thickness steel plate welded all around the base of the riser to form a watertight connection. The plate should be square with each side equal to two times the riser diameter. The plate should have 2 feet of stone, gravel, or tamped earth placed on it to prevent floatation.

- Trash Rack - A trash rack consisting of #4 reinforcing bars, 6 inches on center, should be welded across the top of the riser.

- Antiseep Collars - Conduits through embankments should be provided with antiseep collars. All basins should have a minimum of one antiseep collar which is rectangular blocking all potential flow through the backfilled material and extending to the sides of the barrel trench. The horizontal dimension should be a minimum equal to the barrel diameter plus 2 feet. The bottom side of the antiseep collar should extend a minimum of 2 feet below the grade line, and the top side should extend 1 foot above the barrel.

<u>Emergency Spillway</u>

- The minimum capacity for the emergency spillway will be that required to pass the peak flow from the design storm times 1.5 less any reduction creditable to the pipe spillway. Where emergency spillways are used, the channel bottom should have a minimum width of 8 inches.

- Recommended Design - Two recommended designs are: (1) Discharge over the top of dam or embankment. The spillway should be lined with concrete. (2) Earth spillways protected from erosion by vegetation, rock riprap, or other appropriate material.

- Maximum Allowable Velocity - The maximum allowable velocity in the exit channel of an earth spillway should be 6.0 feet per second.

- Vegetative Protection - Provide for the protection of the embankment and emergency spillway by vegetative or other suitable means. See BMP Chapter II.

Freeboard

Freeboard is the difference in elevation between design high water and the top of the settled embankment.

- Minimum freeboard should be 1 foot for sediment basins with an emergency spillway and 3 feet for those with no emergency spillway.

Embankment

- The embankment should have a minimum top width of 8 feet. Side slopes should be no steeper than 2:1. The maximum fill height should be 15 feet.

Information to be submitted in final design plans:

Sediment retention basin designs submitted for review should include the following:

- Specific location of the basin.

- Plan view of dam and the storage basin.

- Cross-section of dam storage basin, and emergency spillway; profile of emergency spillway.

- Runoff calculations for 10-year and 50-year storms.

- Calculations showing design of pipe and emergency spillway.

- Storage computation (stated in acre-feet).

- Total required (acre-feet).
- Total available (acre-feet).
- Level of sediment when storage drops below 0.3 inches per acre of drainage area

METHODS AND MATERIALS

Site Preparation

- Areas under the embankment and any structural works should be cleared, grubbed and the topsoil stripped to remove all trees, vegetation, roots or other objectionable material. In order to facilitate cleanout and restoration, it is recommended that the pool area (measured at the top of the pipe spillway) be cleaned of all brush, trees or other debris.

Borrow Areas

- All borrow areas should be graded, revegetated and left in such a manner that they are well drained and not subject to erosion.

Embankment

- The fill material should be taken from approved designated borrow areas. It should be free of roots, woody vegetation, oversize stones, rocks exceeding 6 inches in diameter, or other objectionable materials. The embankment should be raised and compacted to an elevation which provides for anticipated settlement to design elevation (allow at least 10 percent for settlement).
    - Placement - Areas on which fill is to be placed should be scarified prior to placement of fill. Fill materials should be placed in 6-inch maximum lifts which are to be continuous over the entire length of the fill and approximately horizontal.
    - Compaction - The movement of the hauling and spreading equipment over the fill should be controlled so that the entire surface of each lift will be traversed by not less than one tread tract of the equipment or compaction should be achieved through use of a roller.

Pipe Spillway Installation

- The riser should be rigidly and securely fastened to the barrel and the bottom of the riser should be sealed (watertight). The pipe spillway should discharge at ground elevation below the dam. All pipe joints must be securely fastened and watertight.

- The barrel should be placed on a firm foundation to the lines and grades shown on the plans. Backfill material should be placed around the barrel in 4-6 inch layers and each layer thoroughly compacted with suitable hand-operated equipment to at least 2 feet above the top of the pipe and antiseep collars before any heavy equipment is operated over it.

Emergency Spillway Installation (Lined Earth)

- Spillway should be lined with 4-inch concrete reinforced with 6x6-10/10 wire mesh extending to a minimum of 3 feet down each face of the embankment. Spillway should be a minimum of 18 inches deep with 1.5:1 side slopes. Further design criteria are shown in BMP III-2.

Structural Backfill

- Backfill material should be of the type and quality conforming to that specified for the adjoining fill material. The material should be placed starting at the lowest point of the foundation in 6-inch maximum lifts and hand compacted to equal or exceed the density of the adjoining fill. Lifts should be continuous over the entire length of the fill and approximately horizontal.

Other

The following general construction criteria are critical to successful installation and operation of sediment retention basins.

- Locate the dam to provide maximum volume capacity for silt behind the structure.
- Prepare the dam site by adequate clearing of vegetation and removal of topsoil before beginning dam construction.
- Level the bed for the pipe spillway to provide uniform support throughout its entire length under the dam.
- Securely and rigidly fasten the collar connecting the riser to the barrel (as well as collars connecting sections of the barrel) of the pipe spillway; insure a watertight bottom on the riser; hand tamp fill under shoulders and around the pipe; insure that the outlet invert of pipe spillway is not more than one foot above stream bed.
- Place the fill in not more than 6-inch lifts compacted by construction equipment. A minimum of 2 feet of hand-compacted backfill should be placed over the pipe spillway before crossing it with construction equipment. Fill materials should be free from roots, woody vegetation, oversize stones, rocks or other objectionable material. Frozen material should not be used.

- Construct emergency spillway as per design on undisturbed soil (not on fill). Design width and entrance and exit channel slopes are critical to the ability of the emergency spillway to successfully protect the dam with a minimum of erosion hazard in the spillway channel.

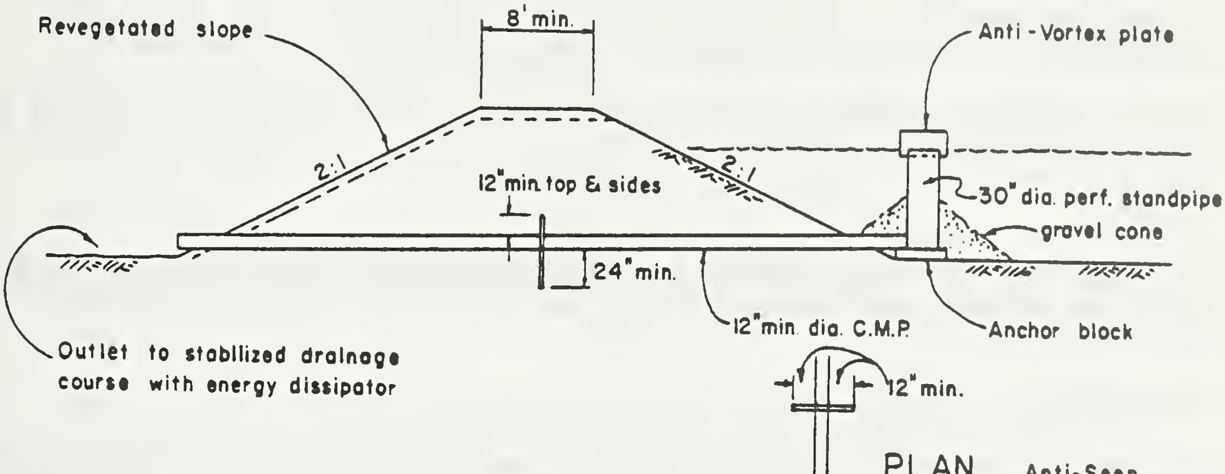
- Stabilize embankment and emergency spillway by slope stabilization and revegetation (BMP Chapter I & II).

MAINTENANCE

- When trap efficiency drops below 0.2 inch per acre of drainage area, the sediment basin should be cleaned out to restore its original capacity.

- A routine schedule specifying personnel, budget, and sediment disposal procedures should be submitted prior to plan approval.

- Sediment should be disposed of in an area that is shown on the plans, approved by ther permit-issuing authority. Location of the disposal site should be to prevent its return to the debris basin or to downstream areas during storm runoff. Disposal areas should be revegetated immediately upon completion of the basin cleaning.



SECTION A-A

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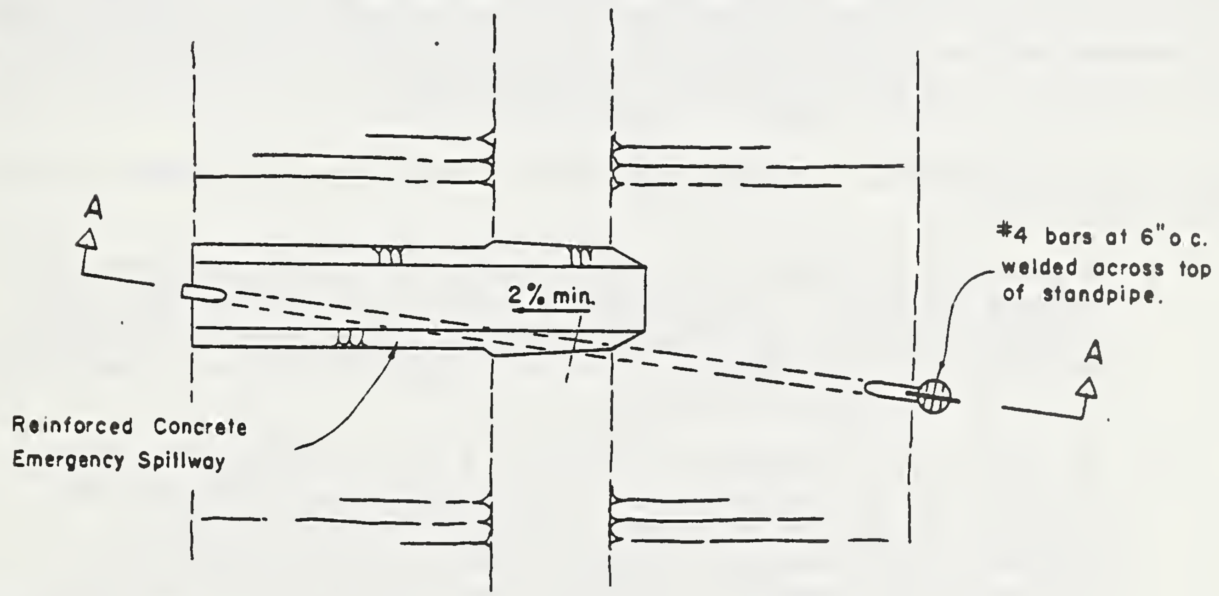

PLAN

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SEDIMENT RETENTION BASIN

Figure V-7

V-9

SEDIMENT TRAP

DEFINITION

A small storage or detention area without special inlet and outlet controls or specific side slopes.

PURPOSE

Sediment traps are used to detain construction runoff long enough to allow the layer size sediment particles to settle out before the runoff is released to downstream areas.

APPLICABILITY

Traps may be used at the toe of embankments where temporary and permanent slope drains discharge, at the lower end of waste areas or borrow pits, and at the downgrade end of a cut section where soil saturation will have no adverse effect. Structures should be built as closely as possible to the source of sediment.

PLANNING CRITERIA

Sediment traps are constructed by excavating a depression, using a natural depression, or by creating an impoundment with a low head dam. By using natural depressions and the existing topography for storage areas and treating only onsite runoff, it is often possible to construct several small traps and avoid construction of the more expensive large traps (basins).

The following information applies to design and installation of sediment traps (See Figure V-9-A).

- In designing a sediment trap in the field, the project engineer should estimate the size of trap required to remove sand size sediment and accomodate the expected volume of sediment to be trapped. If the trap is intended to trap smaller particles, a hydraulic engineer should be consulted for design information.

- The deposition of sediment particles in a trap is a function of the fall velocity of the particles, the trap length and width, and the discharge per foot of trap width. Figure V-9-B may be used to determine trap dimensions required to trap a given particle size. This graph shows percent of sediment load removed on the x-axis and the trap area divided by discharge (LW/Q) on the x-axis. As the length (L) or width (W) dimension increases, the material trapped increases. Relations are shown for a range of particle sizes from 0.004mm to 0.0250mm and for a temperature range from 32^{o} to 60^{o} F. If sediment traps are required on projects where the water temperature exceeds 60^{o} F, use the 60^{o} F curve.

METHODS AND MATERIALS

- Materials for construction of sediment traps vary depending on type. Natural or excavated depresssions require no specific materials other than bare soil. Materials for other types of traps (temporary barriers, filters, culvert risers and vegetative buffer strips) are listed under the respective BMP in this catalog.

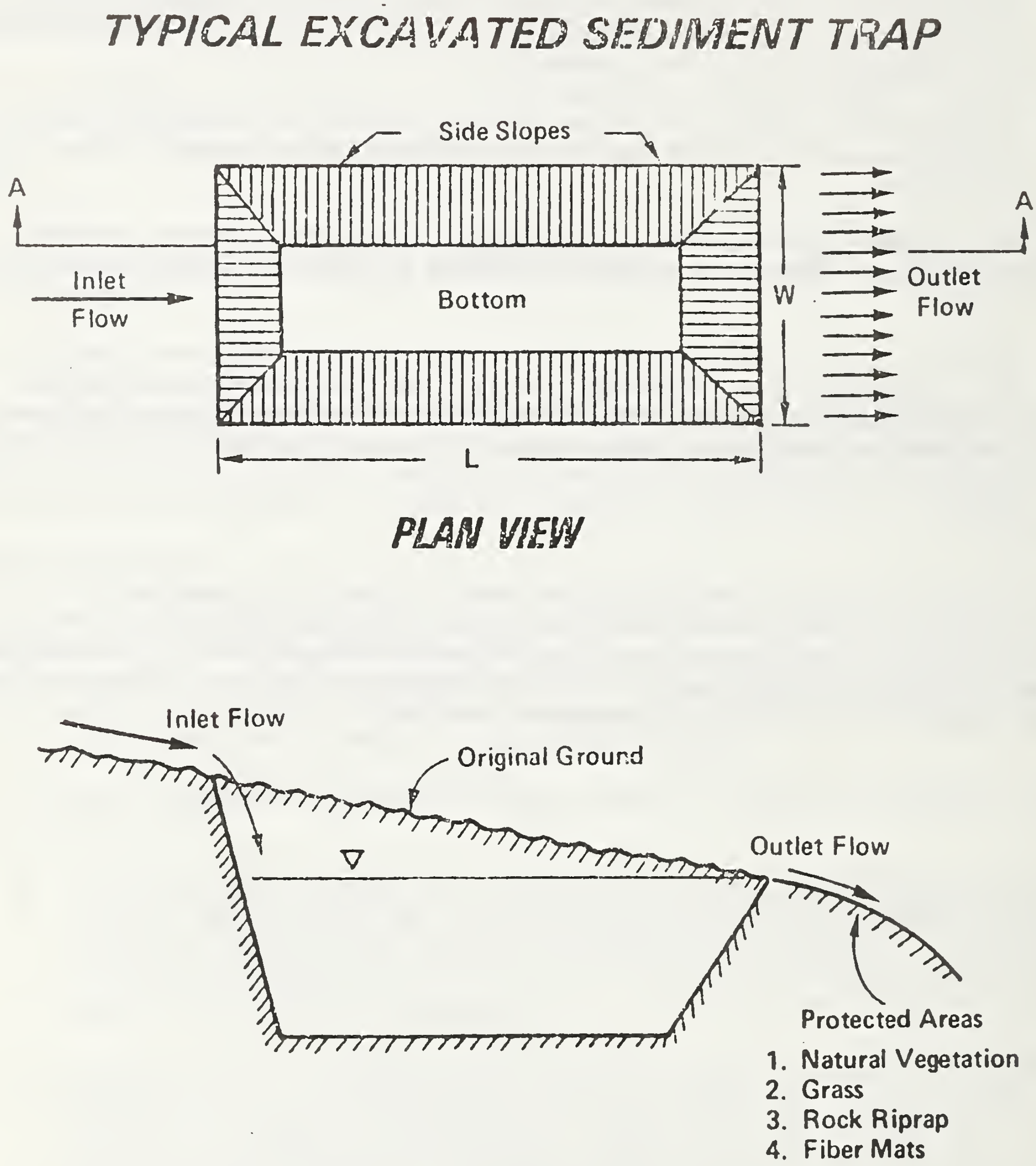
- Sediment traps should be located outside the slope stake limits and should be built prior to the start of excavation or removal of existing vegetation.

- If a trap is constructed by excavation, it may be necessary to remove surrounding vegetation so that equipment can remove sediment from the trap.

- Where a trap is constructed with a filter fence or temporary barrier, it is generally only necessary to clean out the underbrush where the trap is located and in front of the trap. Filter fences and temporary barriers are easy to build and generate minimal disturbance to existing vegetation and terrain.

MAINTENANCE

Inspection and maintenance should be performed regularly as traps may fill up during one storm. Timely removal and safe disposal of accumulated sediment is necessary to maintain storage capacity and ensure sediments are not transported back into work areas or waterways. When the sediment trap is no longer needed, the area should be restored by shaping and seeding.



SEDIMENT TRAP

Figure V-9-A

PERCENT OF SEDIMENT REMOVED FOR DIFFERENT TRAP SIZES, DISCHARGES, WATER TEMPERATURES, AND SEDIMENT SIZES

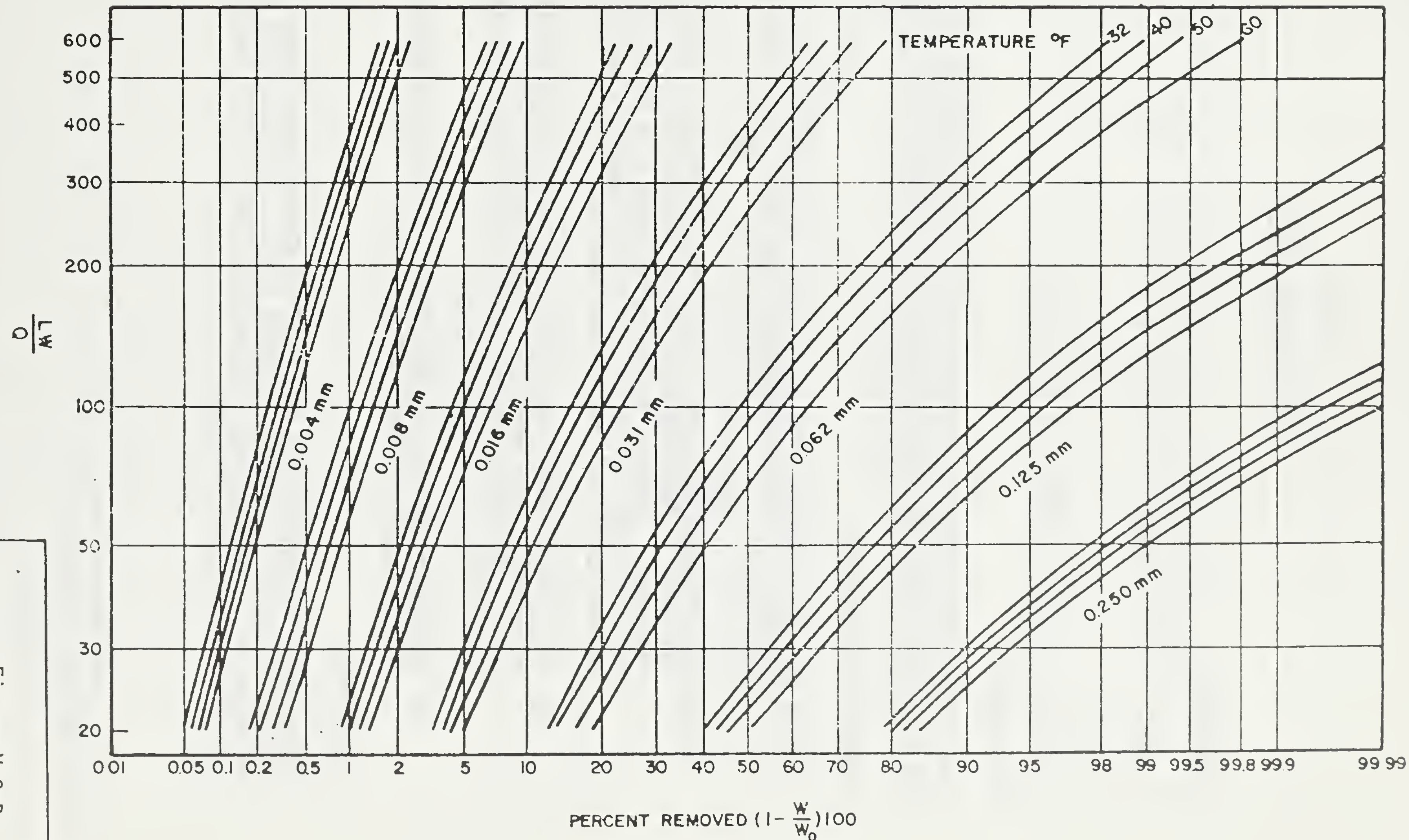


Figure V-9-B

V-9

SLOPE BOTTOM BENCH

DEFINITION

A gently sloping surface at the base of a steeper slope.

PURPOSE

To retain material eroded from the slope.

APPLICABILITY

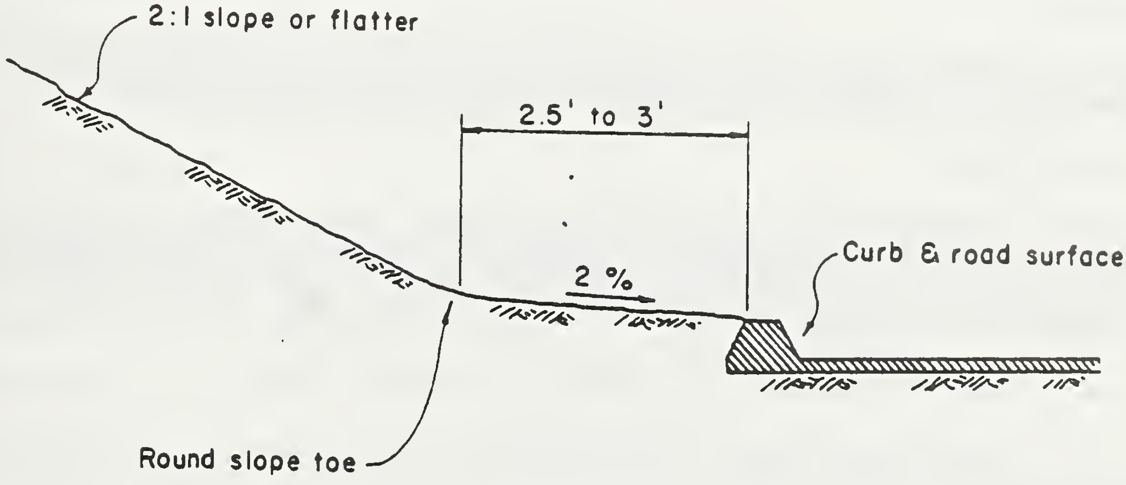
Used for erosion control on existing small oversteepened slopes (20 feet or less) that cannot be regraded because of easement or inaccessability to equipment and on all newly constructed or regraded cut slopes.

METHODS AND MATERIALS

- Install roadside curb and gutter, retaining wall, or other mechanical stabilization facilities where none exists along the slope toe.
- Pull material from the slope with a backhoe or similar equipment and backfill behind the curb creating a bench approximately 3 feet wide. Compact to a finished grade of 2 percent sloping down from the slope toe to the top of the curb or retaining wall. Regrade existing slope face as required (Figures V-9 and I-18.
- For benches constructed along roadways with a grade steeper than 5 percent, the steepness of the bench slope must be increased above 2 percent to prevent lateral water movement behind the curb parallel to the street.
- Revegetate the entire slope face, including the bench, with appropriate method (BMP Chapter II).

MAINTENANCE

Allow material sloughing off the slope to gradually build up. Revegetate bench as required to maintain vigorous growth. Do not remove material deposited on the bench unless the quantity present could cause sloughing into the adjacent curb drainage.



SECTION

no scale

SLOPE BOTTOM BENCH

Figure V- 9

V-10

VEGETATIVE BUFFER STRIP

DEFINITION

A temporary or permanent sediment trap which consists of an area of vegetative cover (native or planted) through which runoff water must flow before it enters streams, storm sewers, conduits, etc.

PURPOSE

Buffer strips collect sediment through interception and detention of runoff water.

APPLICABILITY

Vegetative buffer strips may be placed at any location between the source of sediment (road surface, side slopes) and natural or manmade waterways.

PLANNING CRITERIA

Tall dense stands of grass form the best sediment traps. Sod or planting may substitute for natural vegetation. Planted species should be deep rooted and able to adjust to low oxygen levels (willow, alder). The following widths are suggested for buffer strips.

- Above diversions: 15' plus 1/2 of channel width.
- Along live streams: 100' minimum.

MAINTENANCE

Maintenance is generally not required for natural vegetation, however, planted species should be inspected for growth progress until established. Light fertilization may enhance growth of planted species.

V-11

FLOATING SEDIMENT BARRIER (DIAPER)

DEFINITION

A plastic or other impermeable barrier suspended from floats tied together with a rope and anchored at each end to the shoreline and extending downward to within a few inches of the lake bed.

PURPOSE

Retention of suspended sediment within the disturbed area of a lake, pond or stream.

APPLICABILITY

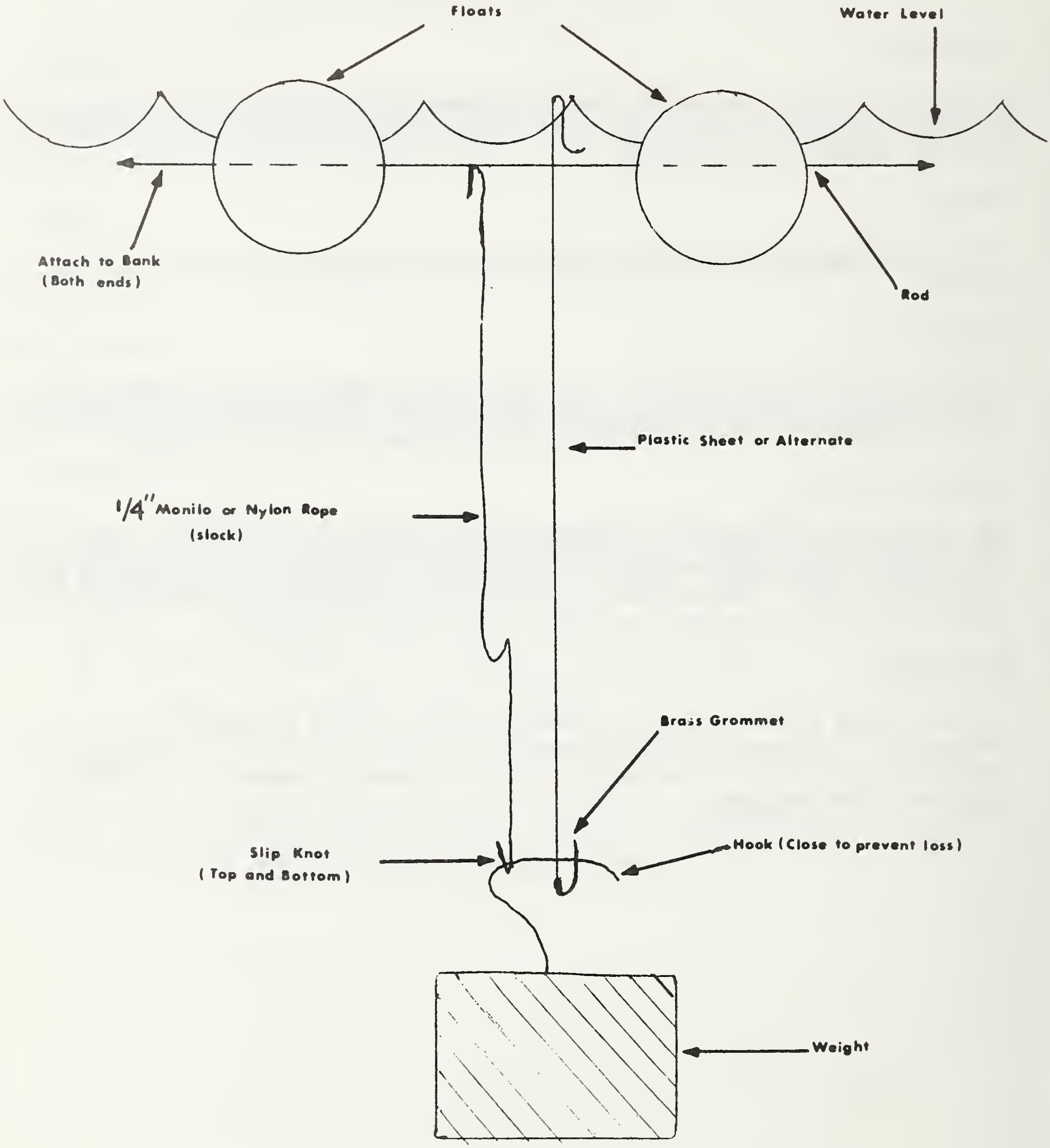
Floating sediment barriers may be placed in any natural waterway where soil disturbance will occur in such close proximity to the water that adequate space is not available for installation of other sediment collection systems.

PLANNING CRITERIA

The sizing and placement of a floating barrier should be sufficient to surround the length of the disturbed bank and extend to the bottom of the waterway bed (See Figure V-11). When earthwork is completed, collected sediment should be removed from within the barrier before the barrier is removed.

MAINTENANCE

Anchors should be checked to make sure they are secured throughout the use of the barrier. Sediment should be removed periodically as well as prior to removal of the barrier. Sediment should be disposed of where it is unlikely to re-enter the waterway.



FLOATING SEDIMENT BARRIER
Figure V-11

V-12

COFFERDAM

DEFINITION

A temporary structure built into a waterway to enclose a construction area.

PURPOSE

To reduce sediment pollution resulting from construction work in and under water.

APPLICABILITY

Construction areas that require excavation or placement of soil and rock within the waterbody (i.e.; bridge, piers, abutments, etc.).

PLANNING CRITERIA

Specific design for cofferdams is not required where:

1) The cofferdam will not provide support for earth pressures
2) hydrostatic pressures are equal
3) waters are calm and less than 10 feet in depth or streamflow is less than 5 cubic feet/sec (cfs), and
4) life is not endangered.

(Where the above conditions are not met, a qualified engineer should be consulted.) Cofferdams should be designed to withstand currents and scour conditions expected under normal stream flow and annual high water. Useful life expectancy of the dam would be 3 months or less.

METHODS AND MATERIALS

Materials of construction commonly include steel sheet piles, rock or wood. Piling could consist of standard steel sheet interlocked and driven into the aluminum or anchored to bedrock. Wooden structures may consist of planks or wood. Where the slope ratio is 2:1 or flatter, rock cofferdams may be constructed.

The inside of the cofferdam may be lined with filter fabric, straw, or some other suitable material that would prevent sediment passage through openings.

MAINTENANCE

Collected sediment and debris should be removed regularly and just prior to removal of the cofferdam.

APPENDICES

APPENDIX A

RUNOFF CALCULATIONS

The fundamental principle of urban runoff management as outlined here is as follows:

> The water falling on a given site should, in an ideal design solution, be absorbed or retained on-site to the extent that after development, the quantity and rate of water leaving the site would not be significantly different than if the site had remained undeveloped.

This appendix provides the basic criteria necessary for estimating quantity of runoff. It is not intended to be an all inclusive definitive design manual nor is it intended to limit the user's creativity.

INITIAL DESIGN CONSIDERATIONS

In order to meet the requirement of limiting the amount of runoff from a site to that of the undeveloped state, it is necessary to consider a number of factors:

1. Rainfall
   a. Historic
   b. Predictable Future
   c. Basis for Design

2. Drainage Area Characteristics
   a. At the Site
   b. Downstream
   c. Upstream
   d. Basin-Wide

3. Land Use Characteristics
   a. Present
   b. Future Short Term
   c. Full Development

4. Design Options
   a. Natural Design and Detention
   b. Landscaping
   c. Maintenance of Vegetative Cover
   d. Detention Storage
   e. Streets and Curbs
   f. Enclosed Collection Systems

5. User Impact
   a. Acceptable Levels of Inconvenience
   b. Preventing Flooding Problems
   c. Minimizing Water Quality Impacts

This appendix provides an analysis of rainfall in terms of a basis for design. The remaining factors, however, must be thoroughly evaluated by the proponent, and a solution must be produced which restricts the runoff as required while still being compatible with the proponent's original design concepts. The importance of considering runoff control during the earliest stages of planning cannot be overstated. Substantial costs savings can be realized by correlating the runoff control system with the earliest design and layout of the development.

RUNOFF QUANTITY DETERMINATION

In order for an individual to determine what types of controls might be adequate for a specific development, it is necessary to evaluate the amount of runoff which can be anticipated both before and after development. The amount of runoff is related to the type of land use and the particular storm which generates the flow.

An analysis of precipitation records indicates that if the "ten percent storm" is retained, then a substantial improvement in the quality of water reaching the receiving streams will result. The "ten percent storm" is defined as that storm producing runoff which will be exceeded by ten percent of the storms which occur during a given year. Therefore, it is necessary to compute the pre-development and post-development runoff from the ten percent storm for the proposed site, and then select a means of retaining the difference between the two quantities. Figure 1 shows the volume and peak rate of runoff which can be expected to result from a ten percent storm. The runoff coefficients used in Figure 1 are summarized for various categories of land use in Table 1. Note that coefficients are also given for specific surface types. If the user can demonstrate that a proposed development will be made up of surface area which is more pervious than the range given for the specific land use, then the runoff coefficient may be altered appropriately.

The following simplified example demonstrates the procedure which should be followed for evaluating runoff:

Given: A small undeveloped parcel of land, intended for development, is presently overgrown with sagebrush and bunchgrass. The soil is sandy with some clay binder.

Find: The runoff volume which must be retained on the site.

Solution:

1. Prior to development the site is estimated to have a runoff coefficient of 0.20 (Table 1).

2. Total Area = 500 ft x 436 ft x 1 acre/43560 ft^2 = 5 acres

3. Runoff volumes before development - v_i = .065 inches (from Figure 1) - $.065 \text{ inches} \times 5 \text{ acres} \times \frac{1 \text{ foot}}{12 \text{ inches}} = \underline{.03}$ acre-feet.

4. After development the site is estimated to have a runoff coefficient of 0.65 (Table 1).

5. Runoff volume after development - v_f = .23 inches (from Figure 1) = $.23 \text{ inches} \times 5 \text{ acres} \times \frac{1 \text{ foot}}{12 \text{ inches}} = \underline{.10}$ acre-feet.

6. Runoff peak flow rate after development - $Q_f = .064 \frac{\text{inches}}{\text{hour}}$ (from Figure 1) = $.064 \frac{\text{inches}}{\text{hour}}$ x 5 acres x 1 cfs/acre-in/hour = .32 cfs

7. Runoff volume which must be retained on site - $v = v_f - v_i$ = .10 acre-feet - .03 acre feet = .07 acre feet.

From the above computations it can be seen that provisions must be made to retain .07 acre feet of runoff water. It should be noted, however, that the amount of runoff which must be retained can be reduced by making design provisions which justify a reduction in the post-development runoff coefficient.

It can obviously be expected that storms which produce much larger quantities of runoff than the ten percent storm will occasionally occur. Although the developer is not required to provide retention for these storms, overflow or outlet facilities should be designed with the necessary capacity to handle this peak flow in order to avoid the likelihood of flood damage.

The runoff which results from the storms, which exceed the ten percent storm, is estimated using the "Rational Method". The "Rational Method" utilizes an empirical formula which takes into account a number of variables related to a storm's intensity, duration and frequency and also related to the drainage characteristics of the land surface.

In the Rational Method, the peak runoff, Q, in cubic feet per second, is computed as follows:

$$Q = CiA$$

in which

C = Runoff coefficient representing the drainage characteristics of the area (see Table 1).

t = Time in minutes after the beginning of rainfall for runoff to peak at the point under consideration (see Figure 2).

i = Average rainfall intensity in inches per hour for a duration equal to the time of concentration, t, for a selected rainfall frequency (see Figure 3).

A = Size of the drainage area in acres.

The time of concentration, t, is related to the slope and the runoff coefficient as shown in Figure 2. The intensity, i, is related to the frequency of the storm and its duration as shown in Figure 3.

The Rational Method is typically used to size facilities which must have sufficient hydraulic capacity to significantly reduce the likelihood of flood damage. For this reason, the Rational Method utilizes much more intense (therefore, far more infrequent) runoff events than the ten percent even previously recommended in the Hydraulic Simulation Model. The following runoff event frequencies should be used when calculating flows using the Rational Method:

Land Use Designation	Runoff Event Frequency
Single Family Residential	5 years
Multi-Family Residential	10 years
Commercial	25 years
Industrial	25 years
Open Space	5 years

Good judgment should be exercised when selecting the runoff event frequency. If severe damage or loss of life might result from a runoff event exceeding the selected frequency, it might be justified to use more infrequent storm for sizing a control facility. In the larger developments, it may be adviseable to conduct an economic risk analysis, in order to determine what storm frequency should be considered, based on a comparison of potential losses versus costs to prevent damage.

In the hypothetical example previously discussed, let us assume that the developer chose to channelize the 0.07 acre feet of runoff to a small holding pond. From the previous computations it can be seen that the inlet and outlet of this pond should be designed to permit the peak runoff rate of 0.32 cfs to pass. In addition, however, an emergency overflow should be provided with sufficient capacity to handle the larger, more infrequent storm which is computed using the Rational Method as follows:

Given: Same as in the first example.

Find: The peak flow rate for which the overflow facility must be designed.

Solution:

1. First select the appropriate storm frequency from the values tabulated on the preceding table. For "Multi-family" designating a frequency of 10 years is recommended.

2. The total area has already been determined as 5 acres.

3. The runoff coefficient has already been selected as 0.65 (from Table 1).

4. The slope of the land is next calculated - $S = \frac{\text{max vert rise}}{\text{max travel dist}} \times 100\%$ $s = \frac{\text{contour elev. 925 - contour elev. 900}}{\text{500 feet}} \times 100\% = 5\%$
   (Note that development may alter this slope during construction and the final slope should be used.)

5. The overland time of travel is next determined from Figure 2.

   Enter the figure on the left side with the 500-foot travel distance. Move horizontally to the right across the figure to the five percent slope. Next, move vertically downward to the line representing the runoff coefficient of 0.65. Lastly, move horizontally to the right side of the figure and read the overland time of travel as 12 minutes.

6. The rainfall intensity is next determined from Figure 3.

   Enter the figure at the bottom with the time travel of 12 minutes determined above. Move vertically upward until you reach the line which represents the 10-year storm frequency. From this point, move horizontally to the left side of the figure and read the rainfall intensity as 1.7 inches per hour.

7. The last step is to insert the values found above into the "Rational Method" equation:

$$
\begin{aligned}
Q &= CiA \\
&= 0.65 \times 1.7 \text{ inches/hour} \times 5 \text{ acres} \times 1.0 \text{ cfs/acre-inch/hr} \\
&= \underline{5.7} \text{ cfs}
\end{aligned}
$$

Conclusions:

Emergency overflow facilities must be provided which will handle 5.7 cfs.

It should be emphasized that the previous example is extremely simplified, and it is intended only to demonstrate a generalized procedure. Through a combination of various control described in this report, the developer in the example could probably modify the drainage characteristics of his site to such an extent that very little additional runoff would be expected from the final development.

FIGURE 1

RUNOFF VOLUME & RATE

VS. COEFFICIENT OF RUNOFF

10 PERCENT RUNOFF EVENT

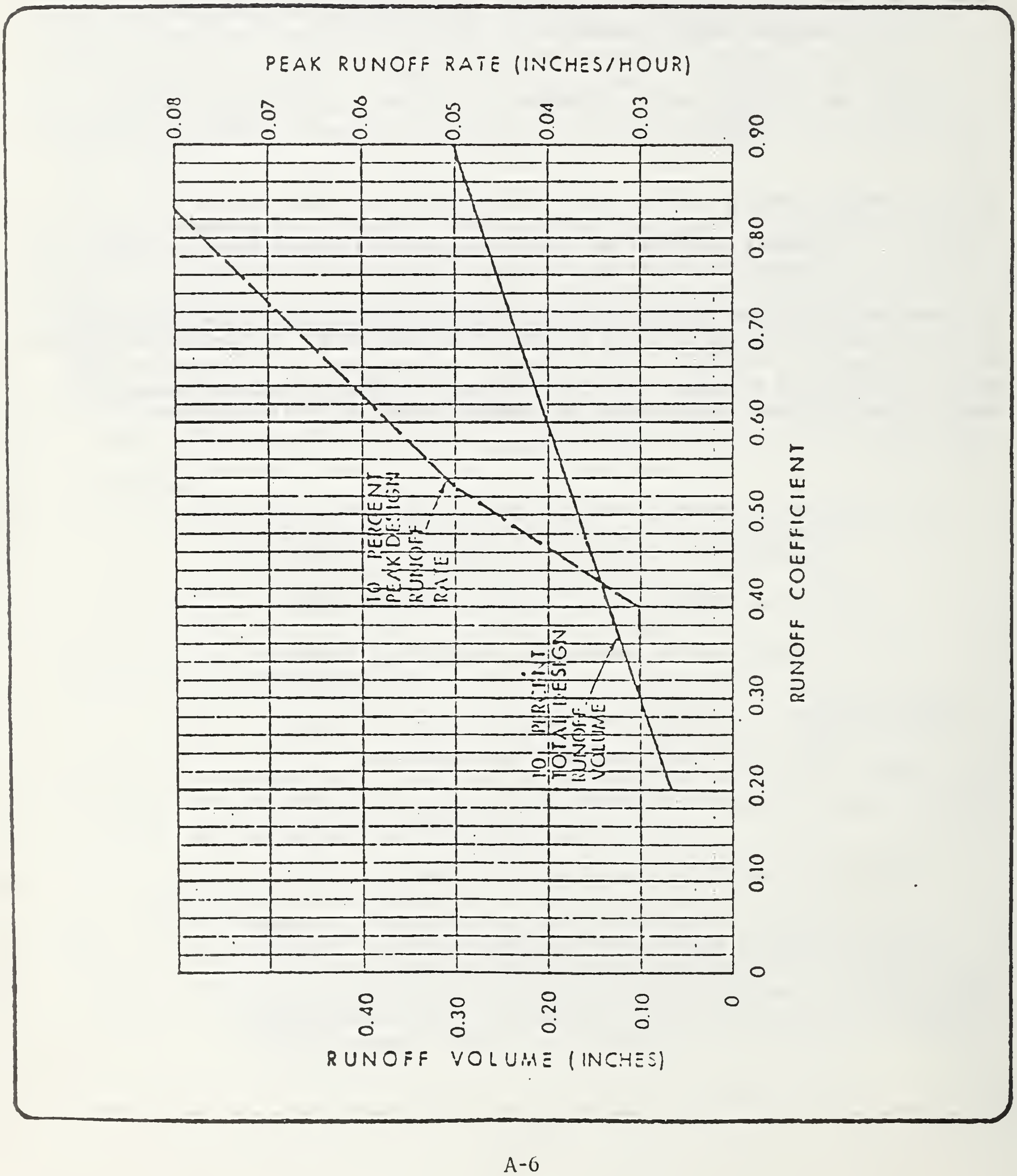


TABLE 1

RUNOFF COEFFICIENTS

Description of Area	Runoff Coefficients
Business	
Downtown	0.70 to 0.95
Neighborhood	0.50 to 0.70
Residential	
Single Family	0.30 to 0.30
Multi-units, detached	0.40 to 0.60
Multi-units, attached	0.60 to 0.75
Residential	0.25 to 0.40
Apartments	0.50 to 0.70
Industrial	
Light	0.50 to 0.80
Heavy	0.60 to 0.90
Parks, cemeteries	0.10 to 0.25
Railroad yard	0.20 to 0.35
Unimproved	0.10 to 0.30
Character of Surface	
Pavement	
Asphalt or Concrete	0.70 to 0.95
Brick	0.70 to 0.85
Roofs	0.70 to 0.95
Lawns, sandy soil	
Flat, 2 percent	0.50 to 0.10
Average, 2 to 7 percent	0.10 to 0.15
Steep, 7 percent or more	0.15 to 0.20
Lawns, heavy soil	
Flat, 2 percent	0.13 to 0.17
Average, 2 to 7 percent	0.18 to 0.22
Steep, 7 percent or more	0.24 to 0.35

FIGURE 2

RELATION OF OVERLAND TIME OF TRAVEL TO OVERLAND TRAVEL DISTANCE, AVERAGE OVERLAND SLOPE, AND COEFFICIENT C

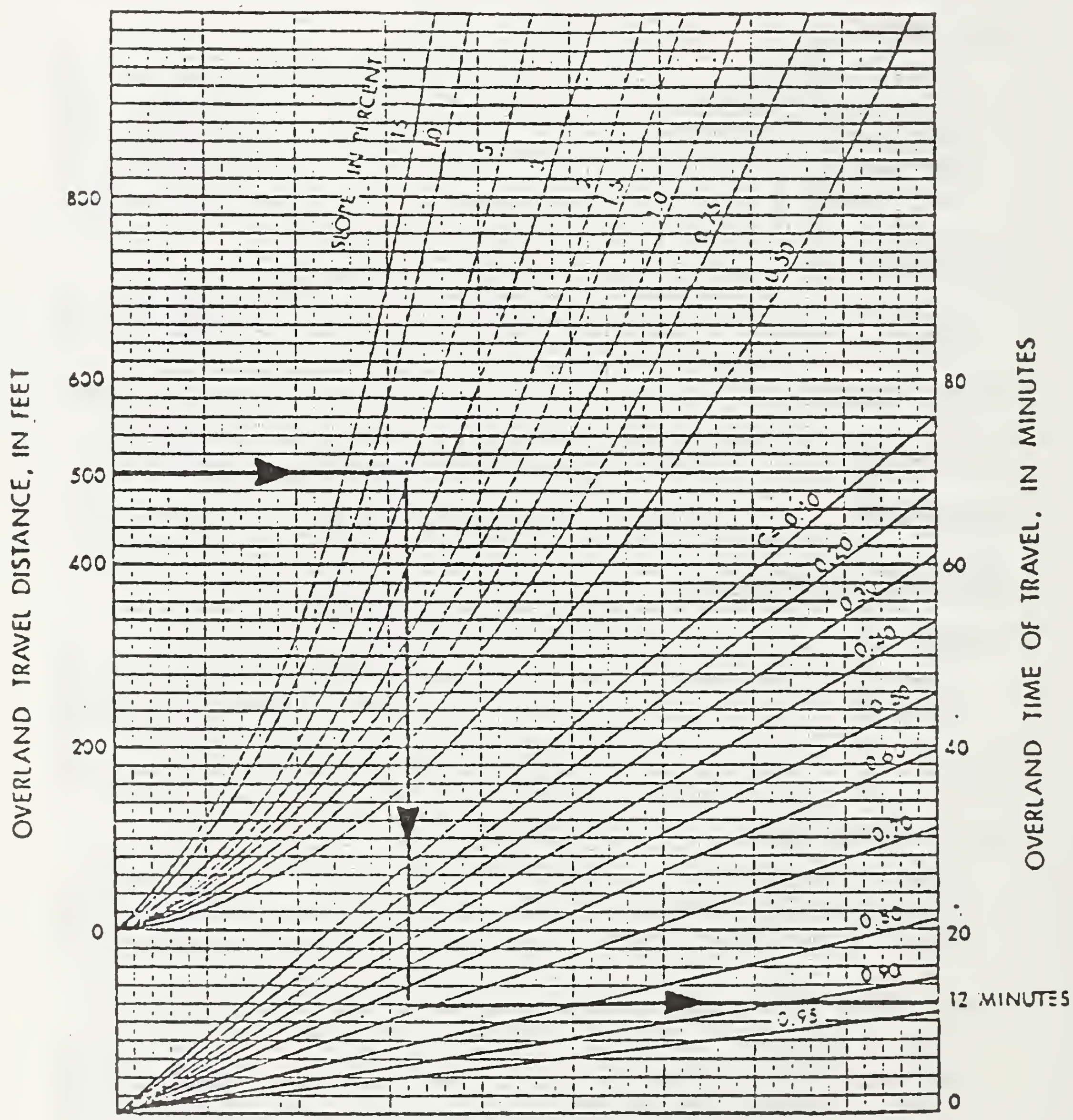
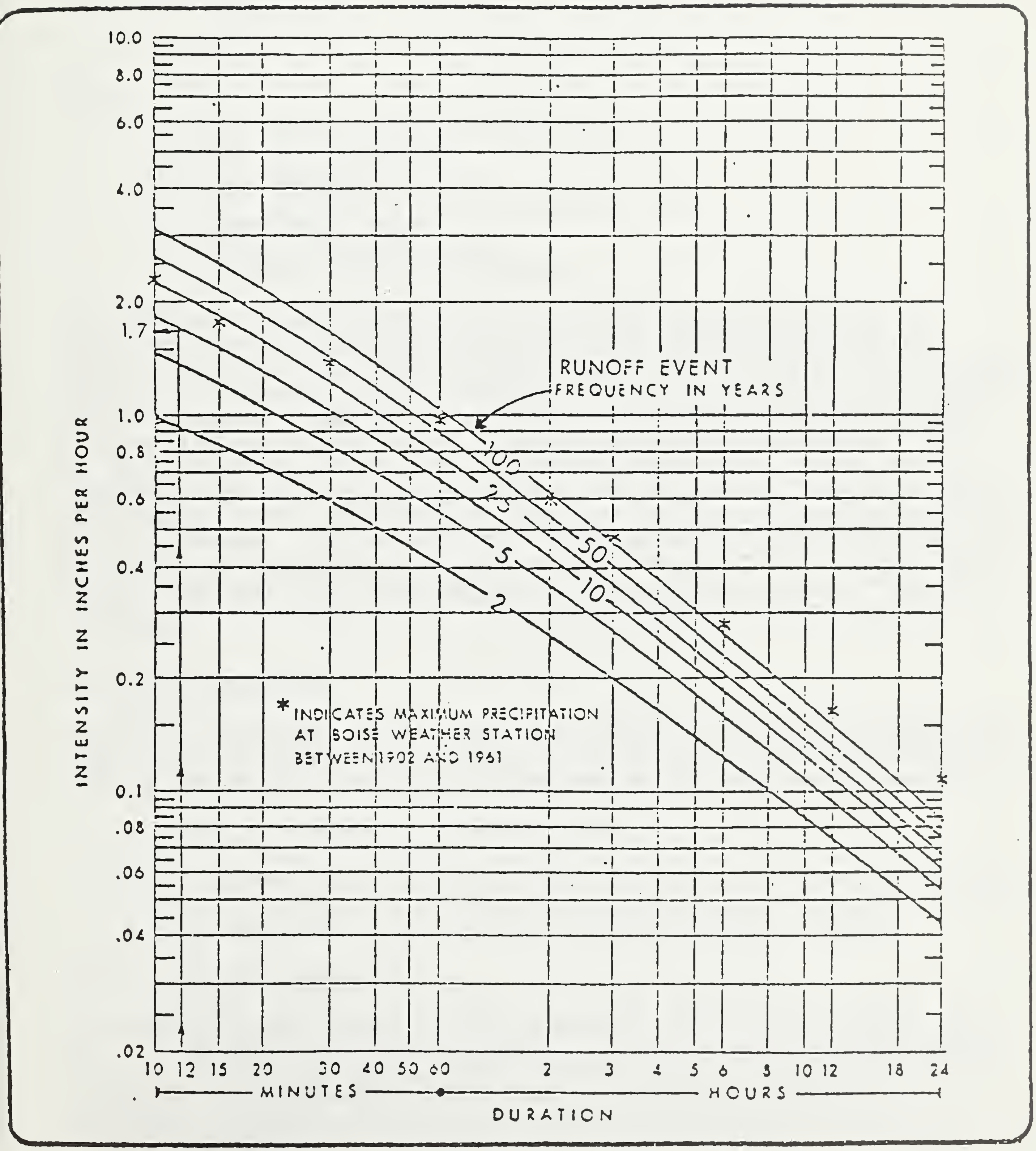


FIGURE 3

RAINFALL INTENSITY, DURATION &

FREQUENCY RELATIONSHIP



APPENDIX B

SOIL LOSS PREDICTION

The universal soil loss equation (USLE) originally was used to predict soil losses caused by rainfall on agricultural land. Modifications allow its use on nonagricultural land and for soil loss by snowmelt and rainfall. The general form of USLE is:

$$A = R_{(T)}KSLCP$$

where:

- A = Soil loss in tons per acre per year
- R_T= Total rainfall factor
- K = Soil erodibility factor
- S = Slope gradient or slope steepness factor
- L = Slope length factor
- C = Cropping management factor
- P = Erosion control practice factor

This procedure can be used to calculate soil loss from the site prior to, during, and after construction and to develop and evaluate erosion control plans for the site. The soil loss quantities predicted by the soil loss equation pertain only to erosion caused by rainfall within a problem area. The equation does not predict erosion induced by runoff originating in the area upstream. It cannot be used to predict soil loss from unstable drainage channels, rill and gully erosion or stream banks. Questions concerning the nature of this relationship and its origin are referred to the publication, "Guides for Erosion and Sediment Control", published in 1975 by the Soil Conservation Service in Davis, California. This procedure defines the methods for determining the values of the factors to be used in the calculations. The evaluation of those factors follows procedures that reflect effects of the conditions that are fixed for the site as well as those that can be modified by means of land management activities.

Calculation Procedures

Predictions of the mean annual rates of soil eroded by rainfall and removed by runoff from a construction site should be made by applying the soil loss equation with the factors evaluated so as to represent the following three conditions.

- Prior to development; undisturbed land.
- During development; disturbed land, temporary erosion measures installed.
- Post-development; land restored, permanent measures installed.

Rainfall Intensity Factor (R_T)

The rainfall erosion index can simply be defined as the erosive force of rainfall. It reflects the combined potential of rainfall impact and turbulence of runoff to dislodge and transport soil particles. "R_S" is the snowmelt factor. It reflects the potential of rapid snowmelt to dislodge and transport soil particles. The sum or "R" and "R_S" factors give the total erosive effect of precipitation (R_t).

For projects which will leave soil bare for periods not equal to one or more complete years, the R_T factor for the appropriate time of exposure should be calculated. Exposure times of less than one year should be measured in months and should include the entirety of each month in which bare soil is present. For example, if a project lays the soil bare on June 19 and establishes cover on August 20, the exposure time is three months: June, July and August.

To calculate R_T for a period of less than one year, prorate the R value for each month based upon the percentage of total mean annual precipitation which falls during that month. Prorate the R_S value by dividing it evenly among the months in which snowfall is significant. Add the prorated values of R and R_S for the months of interest to get R_T. R_T is calculated for periods longer than one year by multiplying the annual R_T value by the number of complete years the soil is to be disturbed and adding the R_T value calculated for the period of time in months not included within complete years. The R_T value for the period less than one year is calculated using the above method of proration.

The values of R, R_S, and R_T should be rounded to 10, 15, 20, 25, 30, 40, 50 and increments of 10 thereafter.

The Soil Erodibility Factor (K) - The soil erodibility factor K is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. The K value of the dominant textural phase of a soil series can be applied to the entire soil series if the erosion potential is about the same for all horizons and textural phases of that series. Where horizons or textural phases of a series differ greatly in erosion potential (two or more K value classes), more than one K value must be assigned to the soil.

In developing K values for soils, use the following soil properties that have been found to affect soil erodibility:

1. Soil texture, especially percent of silt plus very fine sand.
2. Percent of sand greater than 0.10 mm.
3. Soil organic matter content.
4. Soil structure (type, grade).
5. Soil permeability.
6. Clay mineralogy.
7. Coarse fragments in soil layer being evaluated.

The Slope Length-Gradient Factor (SL) - The slope length-gradient factor (SL) describes the combined effect of the topographic features of the site. It is defined as the expected ratio of soil loss per unit width on a field slope to corresponding loss from the basic 9 percent slope, 72.6 feet long.

The two components (S) and (L) influence the transport mechanism which derives its energy from runoff. In flat areas where the effect of SL is negligible, there is little systematic movement away from the site and consequently no soil loss, even though large amounts of soil particles may be detached and splashed around by the raindrops.

The value of the factor SL for a given site may be determined from the curves in Figures B-2 and B-3, which relate it to given values of L and S. Enter either figure from the bottom with slope length in feet, proceed upward to the slope gradient in percent and proceed to the left horizontally to read the SL factor value.

The Cropping-Management Factor (C) - The cropping-management factor (C) is defined

as the ratio of soil loss from land cropped under specified conditions to the corresponding loss from tilled, continuous fallow. In physical terms it describes the effect of protection against erosion provided by vegetation.

Analysis of a large number of field data produced the values of C for different types of agricultural land and percent of ground covers. Extention of the factor C for different types of agricultural land and percent of ground covers. Extention of the factor C to completely different situations is based upon three separate and distinct, but interrelated zones of influence: (1) canopy cover, (2) vegetative cover in direct contact with soil surface and (3) crop residues at and beneath the surface.

Type 1, Canopy Cover. The canopy reduces rainfall erosivity by attenuating the impact of the drops on the soil surface. As such it may be considered as a modifier of the rainfall factor R.

Type 2, Close-Growing Vegetation. It is more effective than equivalent percent cover by canopy because:

- It reduces the impact of the raindrop on the soil surface to zero. It may be thought of then as a modifier of R.
- It reduces the erosive and transportive potential of runoff by slowing down flow velocity through increased resistance. It thus is a modifier of the slope length-gradient factor SL.

Type 3, Crop Residues At and Near the Surface. Crop residues and other organic litter reduce runoff velocity and increase soil erosion resistance. They may be considered then as modifiers of the transport mechanism.

The effects of the three constituents can be determined separately, but for practical purposes they are represented by a single value of the factor C.

Values of C permanent pasture, rangeland and idle land which has been undisturbed, for woodland situations and for construction sites on other disturbed sites are shown in Tables B-1, B-2, and B-3, respectively. Any effectiveness estimate for a control method, such as presented in later chapters on soil stabilization and revegetation (BMP Chapters I and II) can be converted to a C factor value by converting the effectiveness rating in percent to a decimal fraction and subtracting that fraction from one.

The Erosion-Control Practice Factor (P) - The erosion-control practice factor (P) is defined as the ratio of soil loss with the supporting practice to the soil loss with up-and-down-hill culture. In physical terms, it is a factor describing reduction in runoff intensity caused by changing the geometric characteristics of the site. It may be considered then as a modifier of the transport mechanism. For natural conditions, P is set to unity. During construction or other disturbance, P can assume values of from 0.8 to 1.3 as shown in Table B-4. Very little information on the modification of P by using erosion control practices is available for construction and urban types of disturbance.

Soil-Loss Tolerance (T) - Soil-loss tolerance (T), sometimes called permissible soil loss, is the maximum rate of soil erosion (whether from rainfall or wind) that will permit a high agricultural productivity to be sustained economically

and indefinitely. Soil loss tolerance can be substituted for soil loss rate A and the practices, cover and topographic conditions manipulated to achieve the soil loss tolerance. Soil loss tolerance is expressed in tons per acre per year.

Soil Loss Under Existing or Natural Conditions

- Determine the R factor value.
- Use data from topographic maps of existing or natural conditions and Figures B-2 and B-3 to determine the SL factor value.
- Use data from historical vegetation surveys, vegetation mappings, and field surveys of existing conditions or other sources and Table B-1, B-2, and B-3 to determine the C factor value.
- Set the P value at one, unless the judgment of a soils scientist indicates a more appropriate value.
- Multiply all factors together to yield the estimated soil loss in tons per acre per year.

Soil Loss Under Construction Conditions

- Calculate the R factor value for the period of time that the soil is to be exposed during construction.
- Use the same K factor value used in calculating soil loss under existing and natural conditions, unless significantly different horizons or textural phases of the soil are exposed. In this case, recalculate the K factor and apply the new value to the different horizons or textural phases.
- Based upon the proposed project layout and the slope characteristics as shown in the grading plan, determine SL from Figures B-2 and B-3.
- During periods when soil is stripped of vegetation and being graded, set the C value at one.
- From Table B-4 select the appropriate P factor value.
- Multiply all factors to yield the estimated soil loss during construction.

Use of the USLE as a Management Tool

The universal soil loss equation (USLE) can be used to reduce the soil loss during and after construction or other disturbance to the levels existing prior to the disturbance. Soil loss tolerance values should be selected with the aid of permit issuing authorities, soil scientists and water quality consultants.

- Select a T value for use during construction and a T value for use following construction.
- Use the R value determined for the construction period and the R value determined for existing or natural conditions.

- Choose temporary or permanent slope stabilization methods (BMP Chapters I and II) to reduce the slope length and angle factor SL and the cover factor C. Table B-3 gives some C values for these methods.

- BMP Chapter I presents effectiveness values which can be converted to C values as shown below.

- Choose temporary or permanent vegetative stabilization methods to reduce the C factor value. Table B-3 gives some C factors for vegetative stabilization. BMP Chapter II gives some values for these methods.

  - When sediment reduction effectiveness values are available for specific control methods, the percentage effectiveness values should be converted to decimal fractions. The decimal fraction subtracted from one yields the C factor value to be used in the calculations.

    Example: Effectiveness = 97 percent

    97 percent = 0.97

    (1.00)-(0.97) = 0.03

    C Factor Value = 0.03

  - In general, at least one SL, one C and one P factor modifier should be selected to achieve a complete program for erosion control. In some cases, all three may not be needed to achieve the soil loss tolerance desired.

  - If the soil loss tolerance cannot be achieved with the proposed control methods, new methods should be tried. If no combination of methods can achieve the soil loss tolerance level, the project must be modified to reduce its inherent problems so that the soil loss tolerance level can be achieved.

TABLE B-1

(C) VALUES FOR PERMANENT PASTURE, RANGELAND, AND IDLE LAND[1]

Vegetal Canopy: Type & Height of Raised Canopy[2]	Canopy Cover (%)[3]	Type[4]	Cover That Contacts the Surface: Percent Ground Cover 0	20	40	60	80	95-100
No appreciable canopy		G	.45	.20	.10	.042	.013	.003
		W	.45	.24	.15	.090	.043	.011
Canopy of tall weeds or short brush (0.5 m fall ht.)	25	G	.36	.17	.09	.038	.012	.003
		W	.36	.20	.13	.082	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.075	.039	.011
	75	G	.17	.10	.06	.031	.011	.003
		W	.17	.12	.09	.067	.038	.011
Appreciable brush or bushes (2 m fall ht.)	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.085	.042	.011
	50	G	.34	.16	.085	.038	.012	.003
		W	.34	.19	.13	.081	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.077	.040	.011
Trees but no appreciable low brush (4 m fall ht.)	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.087	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.085	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.083	.041	.011

[1]All values shown assume: 1) random distribution of mulch or vegetation, 2) mulch of appreciable depth where it exists, and 3) the site has not been disturbed by mechanical or other means.

[2]Average fall height of waterdrops from canopy to soil surface: m=meters.

[3]Portion of total-area surface that would be hidden from view by canopy in a vertical projection (a bird's-eye view).

[4]G: Cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 inches deep.

W: Cover at surface is mostly broadleaf herbaceous plants (as weeds) with little lateral-root network near the surface, and/or undecayed residue.

TABLE B-2

(C) FACTORS FOR WOODLAND

Stand Condition	Tree Canopy[1] % of Area	Forest Litter[2] % of Area	Undergrowth[3]	(C) Factor
Well stocked	100-75	100-90	Managed[4]	.001
			Unmanaged[4]	.003-.011
Medium stocked	70-40	85-75	Managed	.002-.004
			Unmanaged	.01-.04
Poorly stocked	35-20	70-40	Managed	.003-.009
			Unmanaged	.02-.09[5]

[1]When tree canopy is less than 20%, the area will be considered as grassland or cropland for estimating soil loss. See Table II-B-2.

[2]Forest litter is assumed to be at least two inches deep over the percent ground surface area covered.

[3]Undergrowth is defined as shrubs, weeds, grasses, vines, etc., on the surface area not protected by forest litter. Usually found under canopy openings.

[4]Managed--grazing and fires are controlled. Unmanaged--stands that are overgrazed or subjected to repeated burning.

[5]For unmanaged woodland with litter cover of less than 75%, (C) values should be derived by taking 0.7 of the appropriate values in Table II-B-2. The factor of 0.7 adjusts for the much higher soil organic matter on permanent woodland.

TABLE B-3

COVER INDEX FACTOR (C)
CONSTRUCTION SITES

Type of Cover		Factor (C)	Percent*
None (fallow ground)		1.0	0.0
Temporary Seedings (90% stand):			
Ryegrass (perennial type)		0.05	95
Ryegrass (annuals)		0.1	90
Small grain		0.05	95
Millet or sudan grass		0.05	95
Field bromegrass		0.03	97
Permanent Seedings (90% stand)		0.01	99
Sod (laid immediately)		0.01	99
Mulch:			
Hay rate of application tons per acre:			
	1/2	0.25	75
	1	0.13	87
	1-1/2	0.07	93
	2	0.02	98
Small grain straw	2	0.02	98
Wood chips	6	0.06	94
Wood cellulose	1-3/4	0.1	90
Fiberglass	1/2	0.05	95
Asphalt Emulsion (1,250 gals/acre)		0.02	98

Fiber matting, excelsior, gravel and stone also may be used as protective cover. Effectiveness of these methods ranges from 80 to 99 percent, depending upon method and rate of application. (C) factors range from 0.2 to 0.01. The application rate and estimated coverage of the soil resulting from that rate should be compared with the coverage of other mulch application rates to determine the value of (C) in the specific case.

*Percent soil loss reduction as compared with fallow ground.

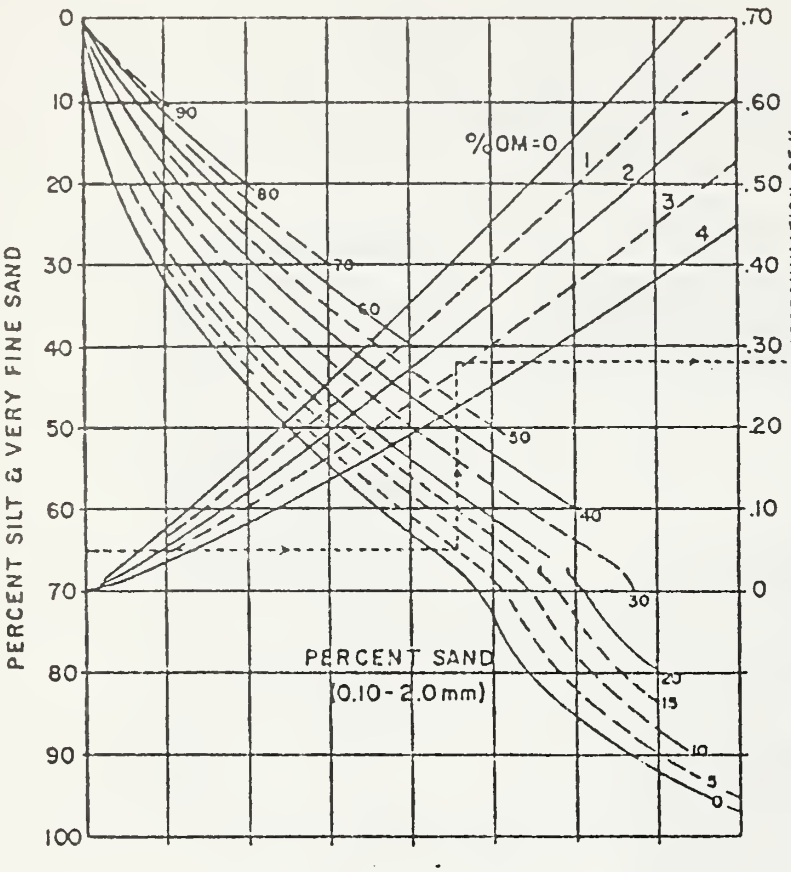
SOURCE: Soil Conservation Service

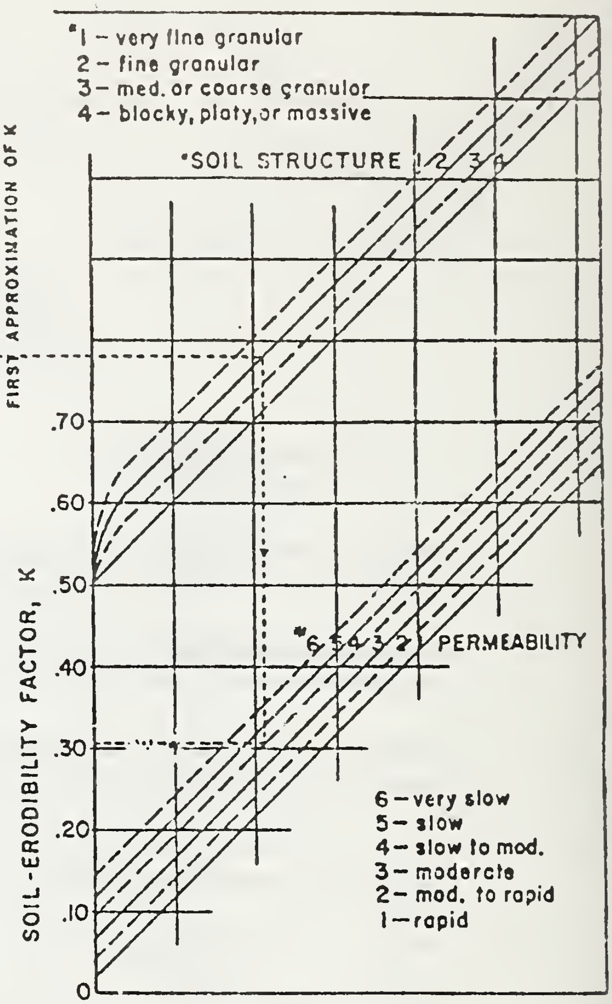
TABLE B-4

PRACTICE FACTOR P
OR SURFACE CONDITION
FOR CONSTRUCTION SITES

Surface Condition With No Cover	Factor P*
Compact and smooth, scraped with bulldozer or scraper up and down hill	1.3
Same condition except raked with bulldozer root rake up and down hill	1.2
Compact and smooth, scraped with bulldozer or scraper across the slope	1.2
Same condition except raked with bulldozer root rake across the slope	0.9
Loose as a disced plow layer	1.0
Rough irregular surface equipment tracks in all directions	0.9
Loose with rough surface, greater than 12" depth	0.8
Loose with smooth surface, greater than 12" depth	0.9

*Values based on estimates.





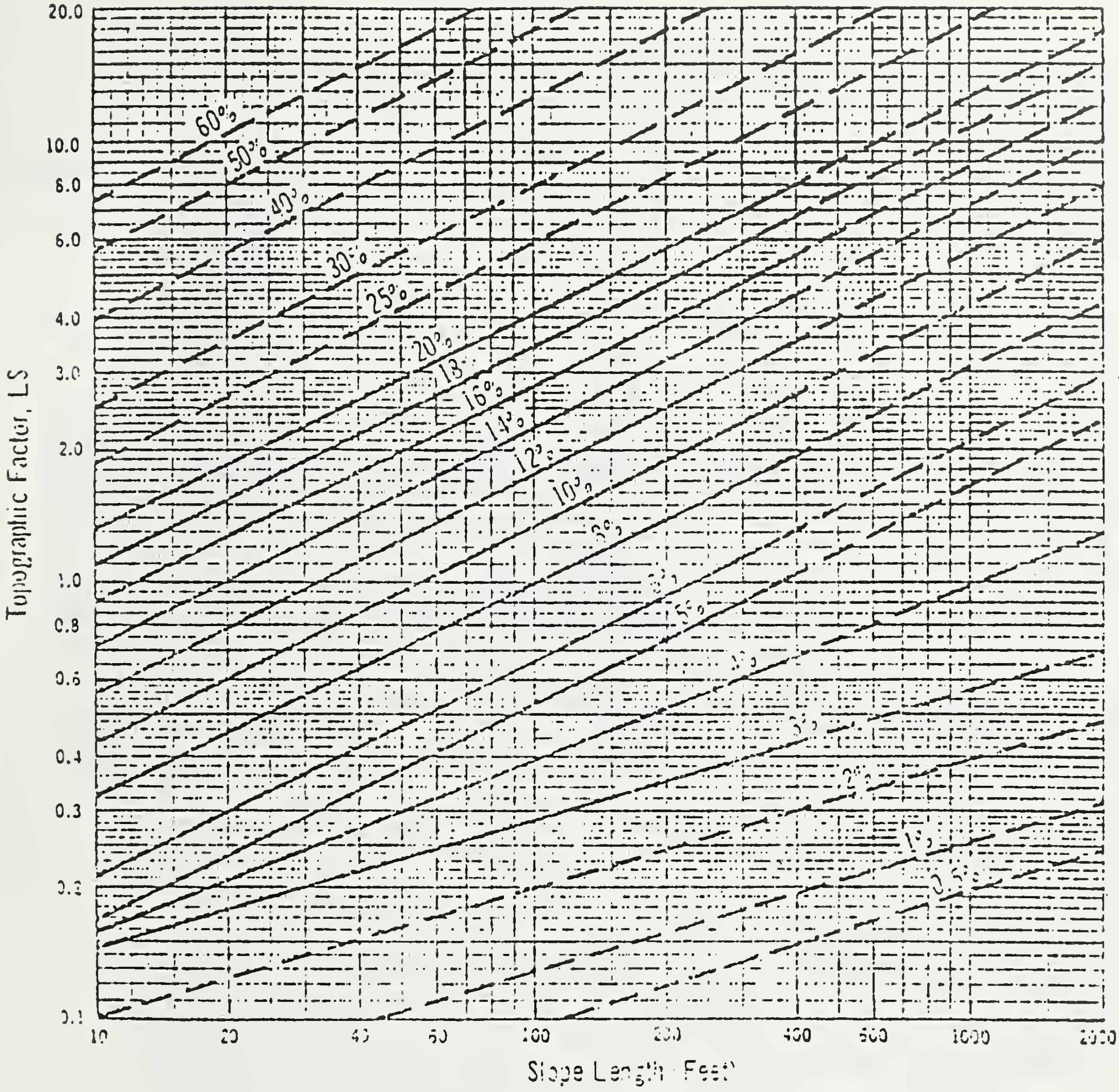
PROCEDURE: With appropriate data, enter scale at left and proceed to points representing the soil's % sand (0.10-2.0 mm), % organic matter, structure, and permeability, in that sequence. Interpolate between plotted curves. The dotted line illustrates procedure for a soil having: si + vfs 65%, sand 5%, OM 2.8%, structure 2, permeability 4. Solution: K = 0.31.

SOIL ERODIBILITY NOMOGRAPH

Figure B-1

Figure B-2

SLOPE-EFFECT CHART (Topographic Factor, LS)*

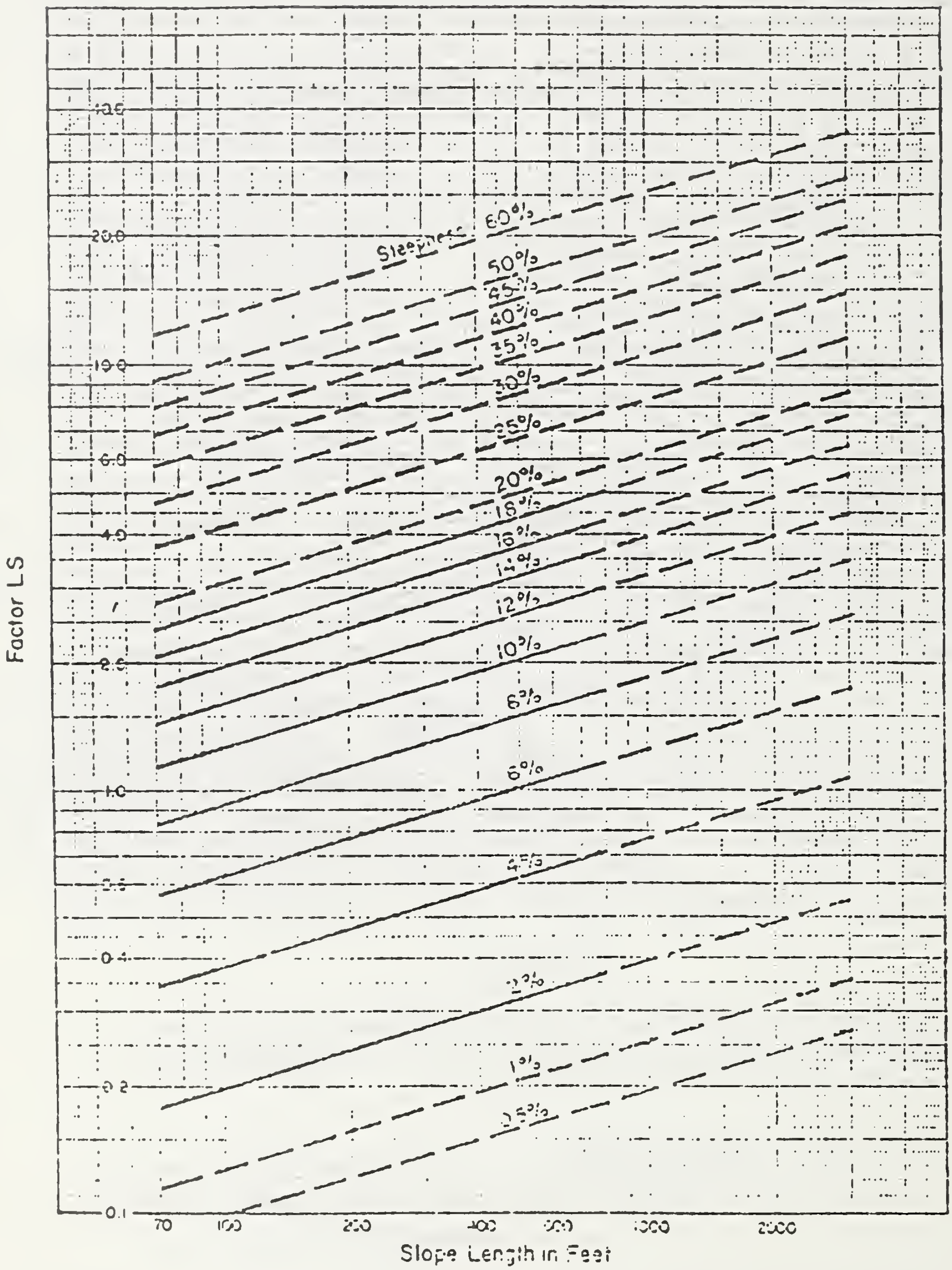


*The dashed lines represent estimates for slope dimensions beyond the range of lengths and steepnesses for which data are available. The curves were derived by the formula:

$$LS = \left(\frac{\lambda}{72.6}\right)^m \left(\frac{430x^2 - 30x - 0.43}{6.57415}\right)$$

where λ = field slope length in feet and $m = 0.5$ if s = 5% or greater, 0.4 if s = 4%, and 0.3 if s = 3% or less; and $x = \sin\theta$. θ is angle of slope in degrees.

Figure B-3



Steepness 60%
50%
45%
40%
35%
30%
25%
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
1%
0.5%
Factor LS
Slope Length in Feet

APPENDIX C

SLOPE CONFIGURATION

AND

DETERMINATION OF MAXIMUM SLOPE LENGTH

All grading, filling and clearing operations should be designed to:

- Preserve, match or blend with the natural contours and undulations of the land.
- To retain all possible existing vegetation.
- To minimize required earth work and scars from cuts and fills.

Maximum Slope Angle - The maximum slope angle shall not exceed the angle of repose of the soil composing the slope as determined by soil report or other available information. An angle greater than two horizontal to one vertical is highly undesirable unless the slope is composed of solid rock.

Maximum Slope Face Length - Should not exceed the maximum length as suggested under "Determination of Maximum Slope Length" to prevent surface erosion under the local environmental conditions of the site.

Slopes of total length greater than specified should be provided with diversions, wattling, infiltration trenches, or other mechanical stabilization devices to limit uncontrolled surface runoff.

- Retaining walls, gabions, and wattling (BMP Chapter I) can be used to reduce slope face lengths on slopes composed of noncohesive soils or moraines.
- Slope benching can be used on large slopes in loose soil to provide sections of slope at the design gradient separated by benches approximately 8-10 feet wide. These benches can provide access for revegetation in addition to interrupting the slope face. Diversion dikes (BMP III-4) should be placed on all benches and at the top of such slopes.
- Slope serration and slope stepping (BMP IV-8 and BMP IV-9) can be used to provide slope face interruption and revegetation on slopes constructed in soft rock.

Erosion Prevention - If erosion will occur above the soil loss tolerance specified in Appendix B, the slope angle should be reduced, the slope should be mechanically stabilized using BMP Chapter I or the slope should be revegetated using BMP Chapter II.

Setbacks - These setbacks are minimum and should be increased if required for safety or stability or to prevent damage from water, soil or debris.

- Tops of cut slopes should not be nearer to a property line than 3 feet, plus 1/5 of the height of the cut, but need not exceed a horizontal distance of 10 feet.

- The top of any cut slope should be a minimum distance of 6 feet measured horizontally from any fill slope.

- Building foundations should be set back from the top of a cut slope a minimum distance of 6 feet.

- Top and bottom of fill slopes should be located so that no portion of the slope will be closer than 10 feet to any adjacent property line. In addition, the toes of fill slopes should not be nearer to any adjacent property line than one-half the height of the fill, but need not exceed a horizontal distance of 20 feet.

Slope Shape - Cut slopes should be constructed utilizing combinations of slope length and angle to produce the most effective and economical configuration. The optimum shape consists of a rounded top, contoured into a uniformly sloping face, with a rounded toe and slope bottom trench.

Mechanical Stabilization - should be screened with vegetation if facilities consist of other than native materials.

Subsurface Exploration - should be conducted at locations where a fill slope is to be placed above a cut slope, at proposed cuts or fills exceeding 20 feet in height, where fills are to be placed on side hills with slopes steeper than 16 percent, or where groundwater may reduce the subsurface stability. The data gathered should be used in designing the slopes to minimize erosion and in designing slope stabilization.

DETERMINATION OF MAXIMUM SLOPE LENGTH

This procedure describes the calculations necessary to space slope interruption facilities required to minimize erosion where long uninterrupted slope face lengths would otherwise exist. Assumptions in the formula derivation include the following:

- No sloughing of slope material.

- No erosion from raindrop impact.

- No infiltration of surface water into the slope.

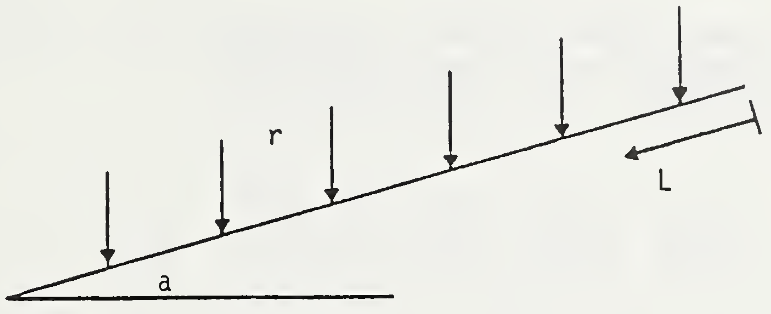
- Uniform flow of surface runoff down the slope.

Practically, this means that the length calculated will be approximate and the method cannot be applied to oversteepened slopes that are physically unstable and sloughing.

Derivation

For the slope shown schematically below,

a = Slope angle
r = precipitation intensity (in/hr)
L = Slope length (ft)
q = surface water runoff rate per foot of width (ft^2/sec)



The flow rate, q, at any length, L, for one foot width is:

$$q = rL \cos a$$

By Manning's Equation for one foot of width

$$q = \frac{D\ 1.49\ R^{2/3}\ S^{1/2}}{n}$$

where:

D = depth of flow
R = hydraulic radius
S = channel bottom slope
n = Manning's coefficient of roughness

For one foot of width:

$$R = D$$

and

$$q \simeq \frac{1.49\ D^{5/3}\ S^{1/2}}{n}$$

or $$rL \cos a \simeq \frac{1.49\ D^{5/3}\ S^{1/2}}{n}$$

and

$$L = \frac{1.49\ D^{5/3}\ S^{1/2}}{nr \cos a}$$

For a given soil, t_{cr} is defined as the critical shear stress or critical tractive

force at the point of incipient motion of soil particles. This is therefore the soil strength above which erosion will occur. The value of t_{cr} can be determined in the laboratory for noncohesive soils from a hydraulic flume analysis and for cohesive soils in a rotating cylinder.

For uniform flow, the critical shear stress is:

$$t_{cr} = Y\ DS$$

where:

D = water depth
S = slope of the energy grade line which in uniform flow is parallel to the channel bottom or the slope surface.
Y = unit weight of water

Therefore:

$$D = \frac{t_{cr}}{Y\ S}$$

and

$$L = \frac{1.49}{nr \cos a} \quad \frac{t_{cr}}{Y\ S}^{\quad 5/3} \; S^{1/2}$$

or

$$L = \frac{1.49 \quad \frac{t_{cr}}{Y}^{\quad 5/3}}{rn \cos a \quad {}^{7/6}}$$

CALCULATION PROCEDURE

- Determine the value of t_{cr} in pounds/square foot using laboratory tests or soil survey data.
- Determine the slope angle a in degrees.
- Determine the channel bottom slope angle S in feet/feet.
- Determine r in feet/second utilizing Appendix A for a 50 year, 6 hour storm.
- Determine n, Manning's coefficient of roughness.
- Calculate L in feet using the equation given above.

The slope length L, computed by this method is the maximum for the soil conditions, precipitation intensity and angle of slope in question before erosion will occur. Table C shows typical values of L for various soil conditions, precipitation intensities, and slope angles.

TABLE C

TYPICAL VALUES FOR MAXIMUM SLOPE FACE LENGTHS

Soil Strength* (τ_{cr}) (lbs/ft^2)	Slope Angle (S) (ft/ft)	Roughness (n) (degrees)	Roughness (n) (unitless)	Rainfall Intensity (r) (in/hr)	Maximum Slope Length (L) (feet)	Rainfall Intensity (r) (in/hr)	Maximum Slope Length (L) (feet)	Rainfall Intensity (r) (in/hr)	Maximum Slope Length (L) (feet)
0.042	4:1	14	0.04	0.25	208	0.50	104	1	52
0.031	4:1	14	0.04	0.25	132	0.50	66	1	33
0.021	4:1	14	0.04	0.25	64	0.50	32	1	16
0.042	3:1	18	0.04	0.25	132	0.50	66	1	33
0.031	3:1	18	0.04	0.25	84	0.50	42	1	21
0.021	3:1	18	0.04	0.25	36	0.50	18	1	9
0.042	2:1	27	0.04	0.25	120	0.50	60	1	30
0.031	2:1	27	0.04	0.25	72	0.50	36	1	18
0.021	2:1	27	0.04	0.25	36	0.50	18	1	9

*As determined by site soil investigation

APPENDIX D

DESIGN PROCEDURE FOR RIPRAP-LINED CHANNELS

This design of riprap-lined channels is from the National Cooperative Highway Research Program Report No. 108, entitled "Tentative Design Procedure for Riprap-Lined Channels." It is based on the tractive force method and covers the design of riprap in two basic channel shapes, trapezoidal and triangular.

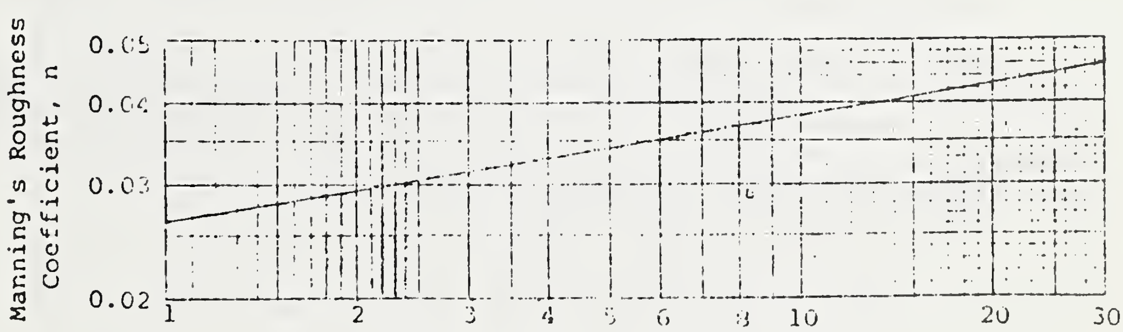
NOTE: This procedure is for the uniform flow in channels and is not to be used for design of riprap deenergizing devices immediately downstream from such high velocity devices as pipes and culverts. See the Standard and Specification for Storm Drain Outlet Protection.

The method in Report No. 108 (design procedure beginning on p. 18) gives a simple and direct solution to the design of trapezoidal channels including channel carrying capacity, channel geometry and the riprap lining. The publication is a very good reference and design aid.

The procedure presented in this Appendix is based on the assumption that the channel is already designed and the remaining problem is to determine the riprap size that would be stable in the channel. The designer would first determine the channel dimensions by the use of Manning's equation. The n value for use in Manning's equation is estimated by estimating a riprap size and then determining the corresponding n value for the riprapped channel from Curve 1, below.

Curve 1 - Manning's "n" for Riprap-Lined Channels

$$n = 0.0395(d_{50})^{1/6}$$



When the channel dimensions are known the riprap can be designed (or an already completed design may be checked) as follows:

Trapezoidal Channels

1. Calculate the b/d ratio and enter curve 2 to find the P/R ratio.

2. Enter curve 3 with S_b, Q, and P/R to find median riprap diameter, d_{50}, for straight channels.

3. Enter curve 1 to find the actual n value corresponding to the d_{50} from step 2. If the estimated and actual n values are not in reasonable agreement another trial must be made.

4. For channels with bends, calculate the ratio B/R, where B_s is the channel surface width and R_o is the radius of the bend. Enter curve 4 and find the bend factor, F_B. Multiply the d_{50} for straight channels by the bend factor to determine riprap size to be used in bends. If the d_{50} for the bend is less than 1.1 times the d_{50} for the straight channel, then the size for the straight channel may be used in the bend, otherwise the larger stone size calculated for the bend shall be used. The riprap shall extend across the full channel section and shall extend upstream and downstream from the ends of the curve, a distance equal to five times the bottom width.

5. Enter curve 5 to determine maximum stable side slope of riprap surface.

Triangular Channels

1. Enter curve 3A with S_b, Q and Z and find the median riprap diameter, d_{50}, for straight channels.

2. Enter curve 1 to find the actual n value. If the estimated and actual n values are not in reasonable agreement another trial must be made.

3. For channels with bends, see Step 4 under Trapezoidal channels.

The riprap size to be specified on the plans should be the maximum stone size in the mixture which shall be 1.5 times the d_{50}. The thickness of the riprap layer is 1.5 times the maximum stone size, but not less than six inches. Freeboard should be added to the channel depth and should not be less than 0.2 times the depth of flow or 0.3 feet, whichever is greater.

Example:

Given:

Trapezoidal channel

Q = 100 cfs
S = 0.01 ft/ft.
Side slopes = 2.5:1
Mean bend radius, R_o = 25'
n = .033 (estimated and used to design the channel to find that b = 6' and d = 1.8')
Type of rock available is crushed stone.

Solution:

<u>Straight channel reach</u>

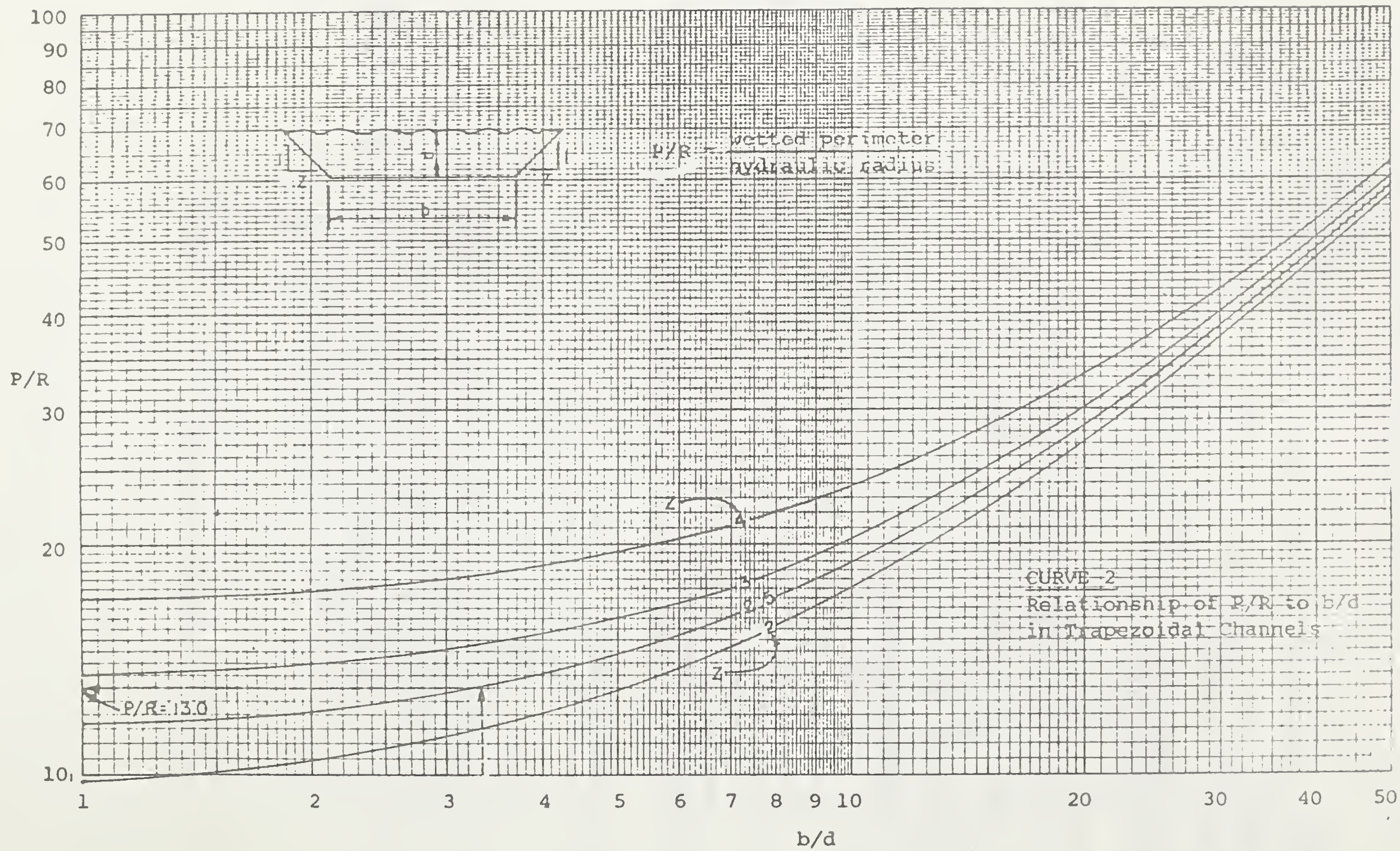
$b/d = 6/1.8 = 3.33$
from curve 2, $P/R = 13.0$
from curve 3, $d_{50} = 3.4"$
from curve 1, n (actual) = 0.032, which is reasonably close to the estimated n of 0.033.
Maximum riprap size = 1.5 x 3.4 = 5.1"
Riprap thickness = 1.5 x 5.1 = 7.7"
<u>Use 5" as maximum riprap size and 8" as riprap layer thickness.</u>

<u>Channel bend</u>

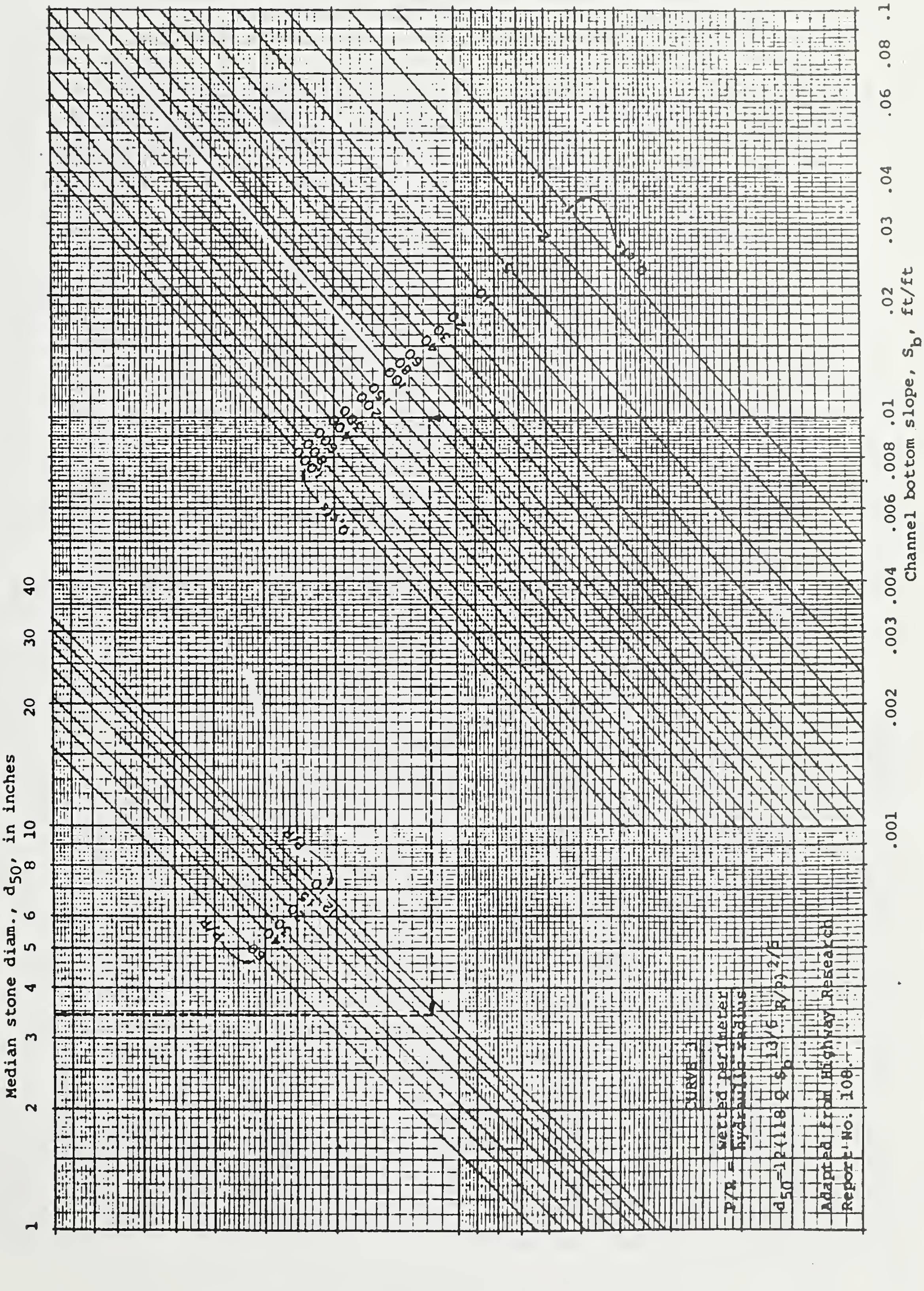
$B_s = b + 2zd = 6 + (2)(2.5)(1.8) = 15'$
$B_s/R_o = 12/25 = 0.60$
from curve 4, $F_B = 1.33$
$F_B = 1.33 > 1.1$, therefore the bend factor must be used.
Riprap size in bend, d_{50} = 3.4 x 1.33 = 4.52"
Max. riprap size in bend = 4.52 x 1.5 = 6.78"
Riprap thickness = 10.2"
<u>Use 7" for max. riprap size and 10" for riprap layer thickness.</u>
The heavier riprap for the bend shall extend upstream and downstream from the ends of the bend a distance of (5)(6) = 30 feet.
From curve 5, it can be found that the riprap for d_{50} = 3.4" and 4.52" will both be stable on a 2.5:1 side slope.

Freeboard = (0.2)(1.8) = .36' but not less than 0.3'
Therefore, minimum freeboard is 0.36'. <u>Use 0.4'</u>

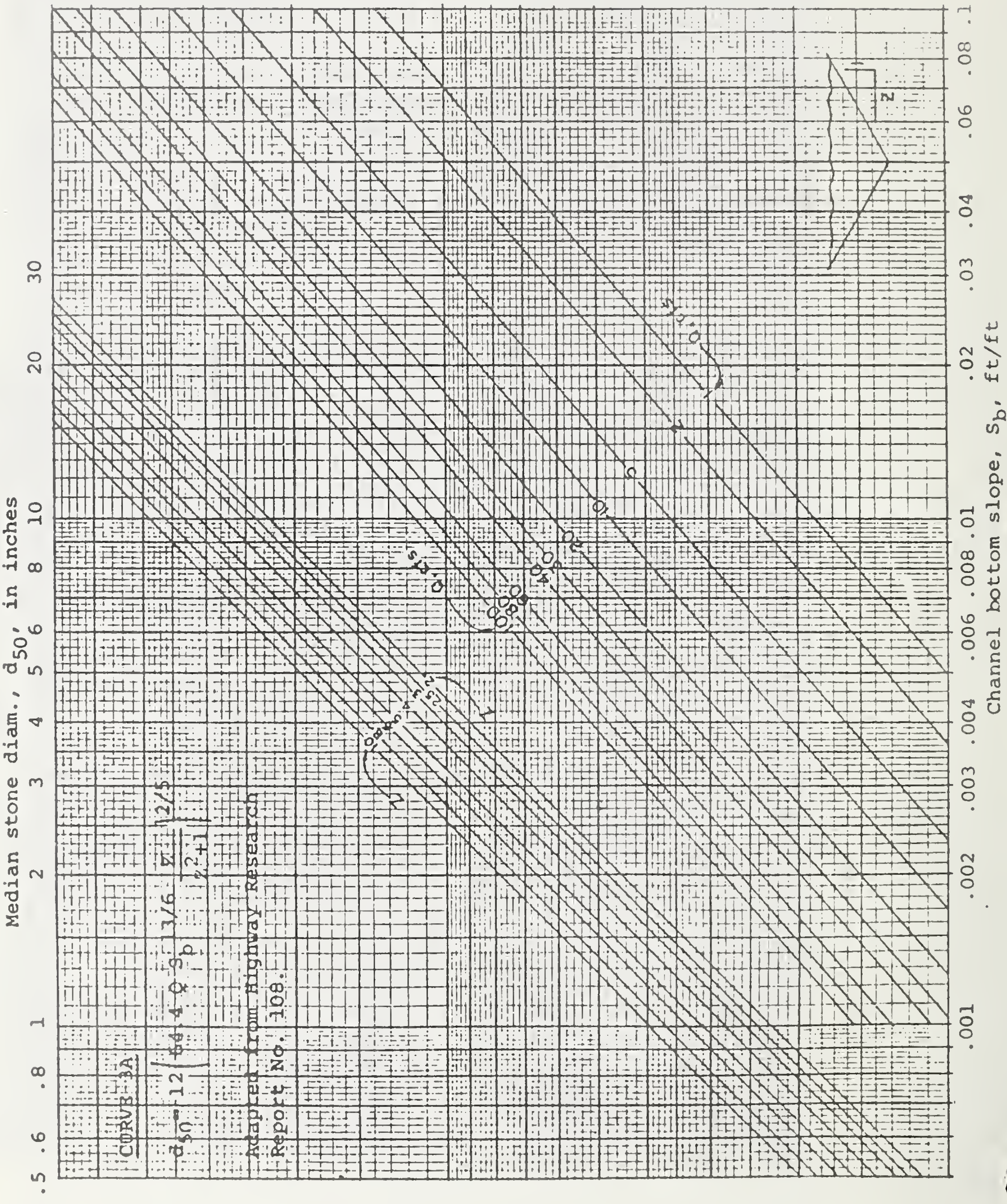
P/R FOR TRAPEZOIDAL CHANNELS



MEDIAN RIPRAP DIAMETER FOR STRAIGHT TRAPEZOIDAL CHANNELS



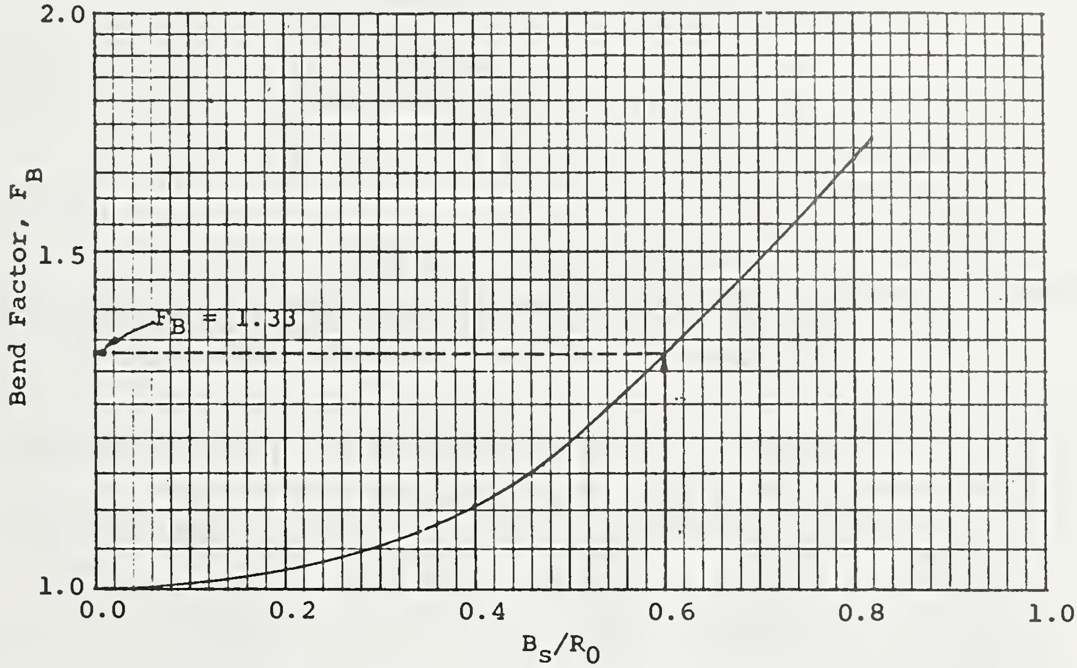
MEDIAN RIPRAP DIAMETER FOR STRAIGHT TRIANGULAR CHANNELS



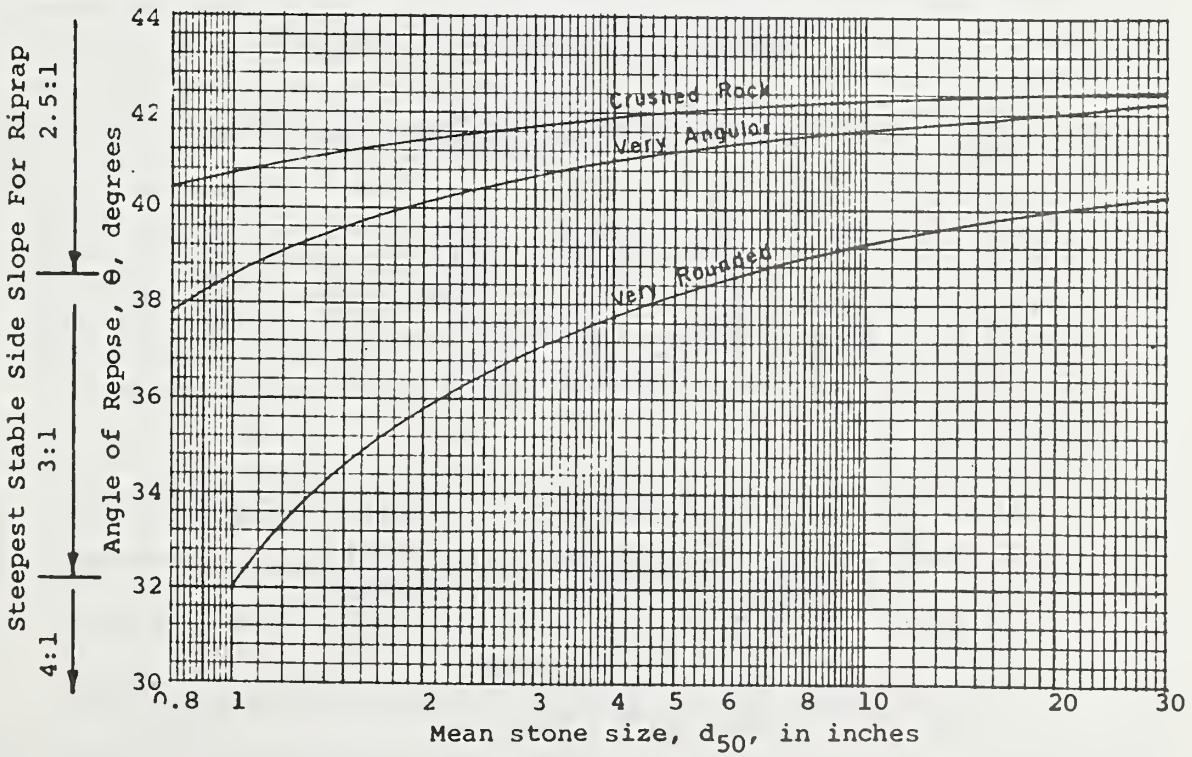
CURVE 4 - RIPRAP SIZE CORRECTION FACTOR FOR FLOW IN CHANNEL BENDS

d_{50}(for bend) = d_{50}(for straight) X F_B
B_s = channel surface width
R_o = mean radius of bend

Adapted from Highway Research Report No. 108.



CURVE 5 - MAXIMUM RIPRAP SIDE SLOPE WITH RESPECT TO RIPRAP SIZE



APPENDIX E

CROSS DRAIN SPACING

For LOW to MODERATELY STEEP Topography:

ROAD GRADE (Percent)	Spacing between open-top culverts (feet)
2- 5	300-500
6-10	200-300
11-15	100-200
16-20	100-

For VERY STEEP Topography:

Forest soil groups in order of (1) decreasing coarseness and increasing detachability of soil on road surfaces and (2) major parent materials in each group

Group 1 → Group 6: decreasing coarseness and increasing detachability of road surface soil

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
hard sediments shale (hard) slate argillite rhyolite rhyolite porphyry limestone (hard)	basalt basalt porphyry quartzite conglomerate gravel	granite sandstone gneiss schist sand	glacial silt shale (soft)	andesite andesite porphyry limestone (soft)	loess

Cross-drain spacings required to prevent rill or gully erosion deeper than 1 inch on secondary logging roads

Road grade (percent)	Soil group on which road is located or built: Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
	Cross-drain spacing (feet)					
2	167	154	137	135	105	95
4	152	139	122	120	90	80
6	144	131	114	112	82	72
8	137	124	107	105	75	65
10	128	115	98	96	66	57
12	119	106	89	87	57	48
14	108	95	78	76	46	37

Table is based on location of road in the upper one-third of north-facing slopes having steepness of 80 percent.

INSTRUCTIONS:

To determine cross-drain spacings for other positions on slope, different exposures, and sidehill slope steepness less than 80 percent, apply the following instructions.

1. If road is located in the middle one-third of a slope, space 18 feet closer than shown. If it is in the bottom third of a slope, space 36 feet closer.
2. If road is located on an east or west exposure, space cross-drains 8 feet closer than shown.
   If road is on a south slope, space 16 feet closer.
3. For each 10 percent decrease in steepness of the sidehill slope from a gradient of 80 percent space cross-drains 5 feet closer than shown.

Summary Results
Concerning
the
Effectiveness and Cost-Effectiveness
of
Labor Intensive Erosion Control Practices
Used in
Redwood National Park

1978 - 1979

\- M E M O R A N D U M   R E P O R T -

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I. INTRODUCTION

Most techniques which have been utilized to control erosion on logged land in Redwood National Park have focused on two principle sources of sediment: (1) sheet and rill erosion from bare hillslopes, and (2) stream channel erosion in natural water courses, at excavated stream crossings and within developing gully systems. The relative importance of each of these two types of erosion is not discussed in great detail within this report. However, most indications suggest that erosion on bare hillslopes is of lesser importance when compared to erosion which is occurring in excavated stream channels and gully systems.

Much of the surface erosion from bare hillslopes never enters active stream channel systems which would eventually transfer debris to Redwood Creek or its major tributaries. It therefore seems questionable, for the sake of erosion control, to provide blanket widespread treatments to control surface erosion on large expanses of bare soils which are not in close proximity to active stream channels. However, treatments used to control sheet and rill erosion on steep side slopes immediately adjacent to stream channels should assume comparatively high importance. While no direct comparison has been made between surface erosion treatments and channel erosion treatments, several of the relatively more expensive techniques which are utilized to control channel erosion could be viewed as more cost effective in the long run. Summary recommendations listed in Table 1 reflect this view.

TABLE 1

SUMMARY OF FINDINGS REGARDING LABOR-INTENSIVE EROSION CONTROL PRACTICES

TECHNIQUE (AS CURRENTLY UTILIZED)	RELATIVE EFFECTIVENESS	RELATIVE COST-EFFECTIVENESS	RECOMMENDATIONS
Check Dams	1	1	Continue use; extend experimental use to larger stream channels and modify design accordingly.
Channel Rocking	1	1	Continue use on small channels in which hand placed rocks can provide adequate protection; rock wetted perimeter of peak flow channel.
Jute With Straw	1	3	Use on steep slopes prone to extensive rilling near streams or gullies.
Straw	1	1	Use at 4,000 - 8,000 lbs/acre on areas where sheet and rill erosion may enter streams or gulies; e.g. excavated stream crossings.
Hydro-Seeding	1	2	Begin extensive test hydro-seeding on one or more 1980 rehabilitation sites.
Wood Chips	1	2	Experimentally apply on large test areas (moderate to steep slopes) where rilling is expected; in-plant with transplants.
Contour Trenches	2	2	Do not use extensively; limited use for dry ravel on steep slopes.
Ravel Catchers (Planter Boxes)	3	2	Limited use acceptable on steep slopes prone to dry ravel only; do not use long boards.
Grass Seed & Fertilizer	3	1	For erosion control purposes, use only if thick, uniform cover can be achieved prior to fall rains; watering may be necessary.
Wooded Terraces	3	2	Do not use as designed; new designs should be tested before widespread use.
Wattles	3	3	Discontinue use.

KEY: 1 = High 2 = Moderate 3 = Low

II. TREATMENTS USED TO CONTROL EROSION ON SLOPES

Most of the following treatments have been widely used in the park. Each of these techniques was compared in terms of their effectiveness in controlling erosion utilizing the following criteria:

(1) Ability to prevent or control rainsplash and sheet erosion.

(2) Ability to prevent or control rill erosion.

(3) Ability to trap sediment which has been eroded from upslope regions.

(4) Tendency to cause secondary problems (e.g. erosional, vegetative, aquatic, water quality, etc.).

Other aspects concerning each treatment that were also examined include:

(1) Percent slope on which the technique has been utilized.

(2) Aspect of hillslope on which the techniques were found.

(3) Quality of construction.

(4) Types of construction materials utilized.

(5) Construction methods.

Also, several mulches which have been quantitatively tested for controlling rill erosion at Site 79-2, and for preventing rainsplash and sheet erosion at Site 79-1 were also examined. While the complete results of these tests have yet to be analyzed, tentative observations have been incorporated within this report.

A. Contour Terracing Structures

Two methods have been used to treat slope erosion. The first involves installation, construction, or excavation of closely spaced rows of terracing structures which contour the hillslope. In general, these "terraces" are designed to disperse concentrated surface runoff and collect and store material which has been eroded from areas between rows, and to a lesser extent promote revegetation.

1. Contour Trenches

a. Advantages - Contour trenches are extremely efficient at trapping sediment derived from upslope rainsplash, sheet and rill erosion. At one location, contour trenches have controlled or stopped the downslope development of sizable rills. If they are not over-topped, the trenches intercept surface runoff and allow infiltration into the soil. This will reduce surface erosion but in some localities may adversely affect local slope stability (e.g. on steep slopes at excavated stream crossings).

b. Disadvantages - Contour trenches do not prevent or control rainsplash or sheet erosion and may actually aggravate these processes by creating small, over-steepened areas. Where infiltration rates are low, surface water collected by the contour trench has filled and overtopped the trench berm causing large rills to develop along its outside edge. In addition, the failure of a single contour trench near the top of the hillslope will result in the overtopping of each and every contour trench which lies in the path of surface runoff which emanates from the failed structure. Overall, this results in the development of large rills and substantial soil loss on slopes which may not have otherwise developed such features.

c. Recommendations - Our observations suggest contour trenches should not be used extensively at this time. They can frequently cause more erosion than they control. If a need does arise, they should only be used where infiltration rates are high. In the future, contour trenches may have limited use in areas with fairly steep (30% to 60%) slopes, good infiltration, and little excess runoff. In such circumstances they may act to inhibit dry ravel and minor surface erosion.

2. Wooded Terraces

a. Advantages - Wooded terraces are very effective at trapping sediment derived from upslope erosion. They provide large, level benches on which the products of upslope rainsplash and sheet erosion, as well as minor rill erosion, may be deposited without being transported further down the hillslope.

b. Disadvantages - Wooded terraces do not prevent rainsplash, sheet, or rill erosion. Construction of wooded terraces results in the creation of a sizable nick point and over-steepened area along their outside edge. Furthermore, they concentrate water and consistently cause rilling where this ponded water is discharged.

c. Recommendations - Wooded terraces have only been used at Site 79-1, although at this site they were used quite extensively. Several of these terraces are already failing after just a single winter's runoff. Judging from the condition of nearby hillslopes which were not treated, wooded terraces appear to cause more erosion through the collection and concentration of surface runoff than they control through the collection of sediment derived from upslope areas. As a result, we do not recommend the continued or widespread use of wooded terraces as a slope erosion control device unless the design is significantly improved. Any proposed design changes should be accompanied by at least one year of experimental application prior to wholesale utilization.

3. Wattling

   a. Advantages - In general, it was found that wattles trap sediment on their terraces to a greater or lesser degree (mostly lesser) and occasionally control a rill that developed on upslope areas. Trapping efficiency depends largely on terrace width. Long-term slope stability may be enhanced if willow or other sprouting species are incorporated in the wattle bundles.

   b. Disadvantages - More often, wattles do not prevent or control rilling, do not prevent rainsplash or sheet erosion, and trap insignificant quantities of eroded sediment. Like wooded terraces, construction of wattles creates over-steepened areas and small nick points across a slope. It was also not uncommon for a wattle to actually concentrate runoff and thereby cause a rill to develop that may not have been formed in the absence of the treatment.

   c. Recommendations - It is recommended that the use of wattling as an erosion control technique be discontinued because of its expense and relative ineffectiveness. Other methods for re-establishing vegetation have met with better success and many less expensive and more effective techniques for surface erosion control have been developed and tested.

4. Ravel Catchers (Planter Boxes)

   a. Advantages - Ravel catchers may be utilized on very steep slopes (60% or greater).

   b. Disadvantages - Because planter boxes are virtually impenetrable barriers to surface runoff, they act to concentrate water and discharge it at discreet locations along the hillslope. As a result, approximately 50% of these areas where planter boxes have been used have shown significant rilling below this point of discharge. Additionally, planter boxes which store large amounts of material on steep hillslopes could potentially fail and deliver relatively significant quantities of sediment into nearby stream channels.

   c. Recommendations - This technique has been used widely throughout the park in a variety of situations. Future use should be restricted to steeper slopes (greater than 50%) that are prone to dry ravel rather than slope failures or significant surface erosion. If use is continued, areas between planter boxes should be treated with some other technique such as a mulch to disperse concentrated surface runoff which may discharge near the "outlet" of each structure. In all cases the use of very long (greater than ten feet) multiple board planter boxes should be eliminated.

B. Surface Treatments

A second set of treatments which have been used to control surface erosion include those techniques which are applied as surface treatments over broad areas rather than as contour-distributive devices which tend to collect erosional products rather than prevent initial sediment movement. Surface treatments are designed to prevent erosion.

1. Grass Seeding with Fertilizer

a. Advantages - The degree of success for surface treatments such as grass seeding and mulch is directly related to the amount of cover which lies in direct contact with the ground surface. Therefore, where grass is thick (covering 90% or better - think of a lawn) rainsplash and sheet erosion is generally controlled (when viewing an area with 90% cover, 10% of the ground surface would be visible). In such conditions, runoff is somewhat dispersed and rill erosion is therefore fairly well prevented. Sediment that does move is frequently trapped by grass clumps and thatch or especially heavy concentrations of growth. Grass also generally looks good (cosmetic), improves soil structure, and is inexpensive to apply (see Appendix A). At Bond Creek (Site 79-1) and Upper Copper Creek (Site 79-4), grass has been locally effective in controlling frost heave, as well as rainsplash, sheet and rill erosion, but was not thick enough to be effective for at least the first half of the winter.

b. Disadvantages - For the most part, grass seeded at the 1978 rehabilitation sites has been ineffective as an erosion control technique. This has occurred because of late seeding, late germination, harsh site conditions, infertile subsoil, spotty and poor application procedures, plus other reasons which have together combined to produce generally poor surface coverage. On all 1978 rehabilitation sites, grass is doing well locally; but, on the average, covers less than 20% of any bare soil area. It appears that at least 80% or better coverage is needed for even minimal erosion control. Finally, reproduction of grasses at 1978 work sites has been very low. While 1979 sites appear to have developed more extensive stands of grasses in response to early seeding and fertilization, even moderate slopes (10% to 30%) show signs of sheet wash which occurred primarily during the first few rainstorms when the grass had not yet been established as an abundant (approaching 90%) ground cover. On slopes over 30%, rill erosion as well as rainsplash and sheet erosion is prevalent. While extensive and repeated fertilization may result in the development of healthy, vigorous stands of grass, such a program would result in local degradation of stream water quality. Fertilizing at the present rates may already be creating algae blooms in many of the streams down slope from

treated areas. Other negative aspects which are associated with grass seeding as currently practiced on rehabilitation sites include:

(1) At the present degree of ground cover, grass only prevents minor rainsplash, sheet and rill erosion (literally none at Site 79-2).

(2) Grass does not trap significant quantities of sediment derived from upslope erosion.

(3) It attracts herbivores onto wet slopes.

(4) Grass appears to compete (fairly successfully) with native species.

(5) It performs very poorly on slopes with hot, dry aspects.

c. Recommendations - All sites which were sampled have been grass seeded and fertilized once, except Site 78-5 which was seeded twice. To this date, a consistently thick cover has not been obtained and may be unobtainable, although a much heavier and rigorous fertilizing program could do much to reach this end. Grass can be an effective erosion control technique provided a thick, consistently uniform cover of grass is obtained prior to the advent of fall and winter rains. However, to reach this end, a more rigorous management program is needed including a well planned fertilizing schedule and a head start on growth by providing irrigation or other watering prior to seasonal rains. If the present program is maintained, some erosional benefits will be achieved but the results will be more cosmetic than sustantive.

2. Hydro-Seeding

a. Advantages - Because a protective mulch layer is sprayed onto the ground surface together with grass seed and fertilizer, hydro-seeding avoids the problem of early rainsplash, sheet and rill erosion which now occurs on broadcast seeded areas. In addition, heavy applications of the bio-degradable wood fiber mulch material, along with grass seed and fertilizer, would result in protection which could approach that of straw mulch which has been spread by hand.

b. Disadvantages - Logistically, hydro-seeding excavated stream crossings and other steep, bare soil areas would require the close coordination and synchronization of rehabilitation activities during the heavy equipment phase of slope and road work. This could be difficult and not always feasible.

c. Recommendations - Although this technique has not been used in the park rehabilitation program as of 1979, it would be one way to provide immediate slope protection to those bare soil areas which would otherwise suffer accelerated surface erosion during the first few winter rains. In addition, the binding action of the mulch, water, seed, and fertilizer mixture is a viable method of producing the thick, consistent cover that is needed to achieve good surface erosion control. As a result, we recommend extensive test hydro-seeding be accomplished at one or more of the 1980 rehabilitation sites, where access is feasible.

3. Straw Mulch

a. Advantages - Mulching bare soil areas with straw has proven to be the most cost effective technique utilized to control surface erosion. It also reduces runoff (promotes infiltration), disperses runoff, retains soil moisture, and keeps the surface soil structure open. On environmentally harsh sites, these factors may combine to aid in a more rapid re-establishment of vegetation.

b. Disadvantages - At heavy application rates (4,000 - 8,000 lbs. per acre) negative effects of straw application may include:

(1) The prevention of seed sprouting and growth (observed reductions of about 25% at 4,000 lbs. per acre rate and about 80% or more at the 8,000 lbs. per acre application rate during the first growing season).

(2) The loss of straw during periods of heavy wind.

(3) The development of potentially unfavorable carbon/ nitrogen relationships in the soil.

On steep slopes composed of loose fill material, a heavy application of straw has the potential to maintain high infiltration rates, possibly causing soil saturation and the development of local, shallow failures. Straw spread at a rate of 2,000 lbs. per acre is not considered as effective as the heavier rates and should be regarded as more of a vegetative technique than an erosion control measure. At this lower rate, rainsplash, sheet and rill erosion are neither adequately prevented nor controlled. However, grass and other vegetation easily grows through this light application of straw; thus, when grass seed and fertilizer is added, greater erosional benefits will be obtained once the grass has grown. Disadvantages of this technique are the same as for grass seed without straw.

c. Recommendations - Straw was spread at all 1979 sites, both by itself and in combination with other treatments. It was primarily spread at a rate of 2,000 lbs. per acre. Straw has been experimentally spread at a rate of 4,000 lbs. per acre (Site 79-1) and at 9,000 lbs. per acre (Site 79-2). Straw spread at rates from 4,000 to 8,000 lbs. per acre is generally effective in preventing and controlling rainsplash, sheet and rill erosion as well as being very effective at trapping sediment derived from upslope surface erosion. Straw's effectiveness in controlling rill erosion appears to be improved by punching the straw into the surface soil. This technique also helps to prevent wind blown straw from leaving the site. On areas of 25% or less slope gradient that do not receive abundant excess surface runoff, the 2,000 lbs. per acre rate is probably adequate. Slopes over 25% should have straw spread at the heavier application rate; the actual rate depends on the potential for excess surface runoff, the steepness of the slope and the inherent erosiveness of the soil material. On slopes over 70%, straw should be secured to the hillslope with jute netting or some other stabilizing agent (see below). In general, straw has proven to be one of the most effective and the most cost effective techniques for controlling surface erosion. Its use should be continued on a widespread basis in areas where erosion of exposed soil would likely contribute significant quantities of sediment to active stream channels or gully systems.

4. <u>Jute-Secured Straw</u>

a. Advantages - Jute over straw is the most effective slope treatment used in the rehabilitation program to control surface erosion.

b. Disadvantages - Revegetation is hindered to a greater extent when jute is used to secure straw to bare slopes. Also, since installation is relatively labor intensive, the relative cost effectiveness of jute-secure straw is lowered considerably by the comparatively higher cost associated with installation.

c. Recommendations - The expensive portion of the installation procedure involves placing and securing the jute over the straw. The actual erosion control device is the straw and surface soil could approach this technique in relative effectiveness (e.g. a heavy application of straw punched in by rollers or by hand could be equally as effective an erosion control measure). In general, most slopes that need to be protected need only the heavy application of straw. Those slopes which are prone to excessive rilling, have a large

volume of surface runoff flowing over them during winter storm events, or are very steep, should be protected with jute over straw. It is recommended that this technique be utilized on steep side slopes at excavated stream crossings where soils are frequently wet and prone to surface erosion.

5. Woodchips

a. Advantages - In general, woodchips prevent rainsplash and sheet erosion, disperse runoff and prevent rilling fairly well, retain near surface soil moisture nearly as effectively as straw and trap sediment derived from upslope erosion.

b. Disadvantages - The most important negative aspect associated with utilizing woodchips (especially redwood chips) to control surface erosion is that they prevent or hamper the germination and/or growth of seeds. In several areas where chips have been spread on ripped road surfaces great expanses of native weeds and grasses have invaded the areas surrounding the chips but very little vegetation has grown within the treated region. Chips also exert demands on soil nitrogen unless they are composted, and are both much more expensive and logistically more difficult to use than straw.

c. Recommendations - Redwood chips have been spread at two locations in the park: Copper Creek (Site 79-3) and Bridge Creek (Site 79-2). A test plot also exists at Site 78-1 (Miller Creek) which consists of various conifer and shrub chips. The test plot at Bridge Creek is the only area where chips have been applied on several test areas on 1979 rehabilitation sites to control surface erosion on moderate and moderately steep side slopes (40% - 60%) of excavated stream crossings. Revegetation of these sites should be accomplished through transplanting rather than through direct seeding. Hardwood or composted chips will decompose more readily than redwood chips and may therefore yield to revegetation efforts more quickly. Fertilizer may need to be applied to achieve favorable carbon/nitrogen relationships in the soil.

III. TECHNIQUES USED IN STREAM CHANNELS

A variety of techniques have been used to control the erosive potential of concentrated surface runoff. These include energy dissipation devices, stream diversion techniques, channel armoring, and water conveyance structures. Only two of these, check dams and channel armoring (rocking) were compared for cost effectiveness (see Appendix B). Other techniques which have been used are briefly described but because of fundamental differences, they could not be adequately compared on a standardized basis.

1. Check Dams

a. Advantages - Excavated stream crossings that have been check dammed have undergone little or no channel adjustment. Check dams prevent channel downcutting, help stabilize channel banks, and provide a stable substrate for revegetation. Channel bank and channel bed revegetation increases long term channel stability through the development of root networks. In at least two sample locations check dams have protected near-vertical banks with no bank failure. Check dams at Bridge Creek (Site 79-2) and Bond Creek (Site 79-1 and Site 78-3) have stabilized stream channels that would have undergone significant channel adjustment and have prevented major bank failures at these locations. Where check dams have been installed after significant channel degradation (i.e. halfway through the first winter), they have halted further downcutting and bank-cutting in unstable stream reaches. Maintenance requirements of check dams appears to be less than originally forecast, with one yearly maintenance period during the winter being sufficient.

b. Disadvantages - No check dams sampled were failing although at one location headward erosion, now taking place below a check dam reach, may eventually cause the upstream structures to fail. Additionally, at one 1978 site and one 1979 site, organic debris had plugged the spillway notch and caused water to back up and scour around the edge of a single check dam. Over the long term, if stream banks and stream bed vegetation is insufficient or poorly established, channel downcutting will occur as check dams begin to deteriorate. This deterioration is expected to begin within ten to twenty years. The yearly maintenance period is also a disadvantage.

c. Recommendations - Bond Creek (Site 79-1 and Site 78-3), Miller Creek (Site 78-1), and Bridge Creek (Site 79-2) all had check dams installed to protect excavated stream channel reaches. At all sites, the check dams have performed excellently, although construction standards at Miller Creek were below that of the other sites. Milling of redwood boards in 1979 has reduced the contract price of check dams while increasing their overall quality (total cost,

including mill workers' time and material has not been determined at this time). We recommend the continued use of check dams at excavated stream crossing sites because of their high success as a labor-intensive technique in stabilizing the channel and preventing both downcutting and bank erosion along potentially unstable reaches. Although relatively costly as compared to measures which control slope erosion, check dams act to inhibit or prevent major erosional problems from developing or enlarging in excavated stream channels and gully systems. Hence, their cost effectiveness must be viewed as extremely high in relationship to other labor intensive techniques which have been applied and in relation to the amount of erosion which has been successfully controlled.

2. Channel Armoring (Rocking)

a. Advantages - Hand rocking stream channels can effectively stabilize stream beds which would otherwise be scoured during winter events. It is also capable of offering some protection to a channel even if part of the rock within a channel is removed by high flows.

b. Disadvantages - Most of the channels rocked by labor-intensive methods have undergone some adjustment during the first winter. Side (bank) cutting is prevalent although many areas also show downcutting. In general, after one season's experience, this technique has not proven as successful as hoped, primarily because of the amount of channel adjustment which has occurred in response to a deficiency in the quantity of rock used to protect the bed and banks and the transport (removal) of smaller rocks which occurs during peak flow periods. Additionally, the use of rock large enough to prevent plucking is determined by the physical limitations of the workers. This disadvantage can be minimized by using horses to transport larger rocks than could be carried by hand. Many sites also lack nearby sources of adequately sized and graded rocks which can be used at stream crossing excavation sites. Finally, maintenance requirements for rocked stream channels is higher than was initially thought, with two or three maintenance periods the first year and perhaps one a season for the next several years being required.

c. Recommendations - Numerous variations of stream channel rocking have been performed within the park, among them double rocking, rocking and staking, and rock and wire reinforcing. Labor-intensive stream channel rocking is most successful if a fairly heterogeneous mixture of rock sizes is used which contain enough large rocks (rocks which will not be moved during peak flows) to keep smaller rocks

in place. This mixture of rocks tends to protect the channel more fully than a homogeneous layer of large rock or a blanket of small particle sizes. Stakes and chicken wire with rebar have been used successfully instead of large rocks to prevent rock plucking, although these techniques have yet to be fully tested and evaluated. Other factors to consider when desiring to successfully rock a stream channel by labor-intensive methods include:

(1) The channel bottom of the excavation should be wide enough to handle peak flows.

(2) The rock should be placed high enough on the side bank to contain peak flows and prevent bank scour.

(3) Enough rock should be used to adequately protect and armor the bed of the channel.

(4) Rock sizes and/or securing techniques should be employed to assure that peak flows do not remove the protective material.

3. Water Ladders, Nick Point Plugs, and Their Variations

a. Advantages - Water ladders, nick point plugs and other related techniques (water flumes, etc.) are all used to convey concentrated runoff over steep sections of hill-slopes. These techniques prevent the headward migration of nick points and major gully headcuts. Although extremely site specific, all uses of these techniques have been successful in controlling continued erosion.

b. Disadvantages - The main disadvantage of these structures is that at some point in time they will deteriorate and fail. It is likely that the erosion being prevented at this point in time will be merely delayed to a later date. Further-more, in the past, the placement of some structures has been questionable due to the relatively small discharge which they carry during the winter months. In these cases less costly techniques such as rock or secured slash could have been used with equal success. Additionally, the construction of structures that would be large enough to contain peak flows of streams with even a moderately high discharge may be physically or logistically impossible, as well as prohibitively expensive.

c. Recommendations - Ultimately, it appears to be more cost effective to perform minor excavations and develop at least partially excavated water courses at locations where nick point plugs or water ladders would otherwise have to be constructed. In areas inaccessible to heavy equipment these

techniques should be relatively cost effective where peak flows would otherwise be sufficient to develop headcuts and form major gullies.

4. Log Deflection Points

Log deflection points have been utilized at only one site (Site 79-1) and although they functioned as intended during several storms (diverting stream flow away from unstable channel banks), the stream has now degraded below the level of the logs and has rendered three of the four deflection points useless (except perhaps at peak discharges). At isolated locations there may be some need for the continued use of these structures in the future. The same results may be accomplished by heavily aromoring the streambanks with rock provided the raw material can be derived locally.

5. Notched Log

This is a relatively minor rehabilitation operation which can be utilized to provide local base levels within a degrading reach of stream channel. Rather than remove large pieces of organic debris that are encountered during excavation or as stream channels adjust by downcutting, logs may be notched (with chain saws) to provide spillways similar to those utilized in check damming. These notched logs then act as local base levels, or check dams, below which stream channels are not likely to downcut.

IV. MISCELLANEOUS TECHNIQUES

1. Energy Dissipators

Most of the energy dissipators used on 1978 and 1979 rehabilitation sites are located at the base of other structures, such as check dams and water ladders. Numerous kinds of energy dissipators have been used and, generally, those made with rock have been the most effective; those using slash, etc., being somewhat less effective and those made from milled or split board being even less effective. An exception to this order has been the utilization of split boards as energy dissipators at the base of check dams in conjunction with wing walls in front of the next downstream check dam. Split boards set in herringbone fashion that were used at Site 78-2 to control minor rill erosion have been rendered totally useless after last season's storms. In the future, herringbone energy dissipators should not be utilized.

2. Manual Excavation, Ditches, Etc.

Manual excavations, general shovel work and other labor intensive activities of this type are considered to be cost effective because there is no alternative to them. The degree of effectiveness is highly dependent on the siting and prior approval of work to be completed, both of which are the responsibility of the Contracting Officer's Representative at the work site. Overuse of manual labor at rehabilitation sites can be extremely cost ineffective if not closely controlled to provide maximum erosion control effectiveness.

3. Waterbars

Waterbar construction, repair, and maintenance is an effective rehabilitation technique, although effectiveness is again dependent on the proper location and construction of these structures. Adequate site mapping and pre-planning for the placement of waterbars is necessary and can result in waterbars being one of the more cost effective techniques used to control surface erosion on rehabilitation sites.

V. CONCLUSIONS

Although many erosion control techniques have been used in the park, none have been one-hundred percent successful. This is due to a variety of reasons, of which the inherent capabilities of the technique is only one. Where the technique is used (generally) and where it is placed (specifically) are also very important factors, as is the quality of construction. It was apparent in some locations that more work should have been done to control erosion, while at other sites, techniques were utilized where no erosion control device was needed. The sophistication of where and when to use a particular technique will only come with experience. Guidelines set forth here should help.

As different labor-intensive techniques are used more extensively in the park, cost-effectiveness data can be refined further. Also, as techniques such as the check dams placed in the 1978 and 1979 sites grow older, more accurate predictions of their longevity can be made. In addition, through the continued use of these techniques, hybrids of methods to fit particular situations will also be made, adding to a technique's effectiveness.

In conclusion, probably the single most important factor in successfully prescribing labor-intensive erosion control techniques is proper site evaluation as to current and expected erosion processes and rates. For example, if the walls of a failed crossing are still vertical after many years, then the emphasis should not be so much to carefully outslope the excavation, but rather to make sure the channel bottom is wide enough to contain peak flows without climbing (or cutting) the banks. If site conditions are harsh with a hot, dry aspect, then the emphasis should be placed in controlling dry ravel and using a mulch to conserve precious moisture. Or, if a site is prone to high amounts of runoff (as evidenced by numerous rills, fans, etc.) then care should be taken to control future rills after the area is redisturbed. A mental noting of these types of signs can do much to aid in the selection of proper rehabilitation techniques.

APPENDIX A

Table 2 lists the slope erosion control treatments in descending order of their relative cost effectiveness. Also listed is their cost range, their average cost (weighted by how much of the technique has been used at a specific cost), the cost of treating a 1,000 square foot plot on a 50% slope (assume a 20 foot by 50 foot area, length going up and down slope), the cost range to treat such an area, the relative erosion control effectiveness of each technique, the cost effectiveness and finally, the cost-effectiveness range. The cost-effectiveness range was determined by the cost range and not by a range of effectiveness.

The effectiveness of each technique was determined in the following method: Upon completion of the field survey of the 1978 and 1979 sites, the results of how each technique fared in the following four categories were tallied and then totalled:

(1) Ability to prevent (control) rainsplash and sheet erosion.

(2) Ability to prevent (control) rill erosion.

(3) Ability to trap sediment which has been eroded from upslope areas.

(4) Tendency to cause secondary problems (e.g. erosional, vegetative, aquatic, water quality, etc.).

From these totals, a percentage of how often a particular technique prevented erosion, trapped sediment or caused problems, was obtained. For example, ravel catchers never prevented or controlled rainsplash or sheet erosion (0%), prevented some rill erosion (17% of the time), trapped sediment most of the time (82%), and caused problems (usually rills) 50% of the time (thus did not cause problems 50% of the time) for an effectiveness value of 149 (0 + 17 + 82 + 50). It should be noted that the numbers that were totalled to create the percentages were for "treatment areas" and not for individual parts of a technique. Using ravel catchers again; if there were six structures at one site and three were causing rills, and six at another site with none causing rills, then the number of ravel catcher <u>sites</u> causing problems would be 50% (causing rills at one site, not causing rills at another).

Cost effectiveness was determined by computing how much of a technique was needed to "cover" the hypothetical 1,000 square foot plot and multiplying this amount by the weighted average cost to obtain a total cost to treat the area. This cost was then divided by the effectivenss to obtain cost effectiveness (this figure was multiplied by 100 to put into a more understandable form).

It should be noted that the numbers in Table 2 are not absolute but are close to what the true relative value of the effectiveness of each technique is. The only effectivenss value that will probably change is the value for straw. As an erosion control technique, straw was generally applied (and hence sampled) at the 2,000 lb/acre rate. Thus, if it is used more at the 4,000 - 8,000 lb/acre rate, its increase in erosion control effectiveness could be more than offset by the increase in percentage of problems caused (primarily, vegetation exclusions). This change in value should not affect its position in the overall ranking scheme. As applications and structures begin to age, and more are installed, individual percentages for each category will probably change but overall values should remain fairly constant.

TABLE 2

COST EFFECTIVENESS TO TREAT A 1000 SQ FT, 50% SLOPE TREATMENT AREA

TECHNIQUE	COST RANGE	WEIGHTED AVERAGE COST PAID IN PARK($)	WEIGHTED AVERAGE COST FOR HYPOTHETICAL TREATMENT AREA ($)	COST RANGE FOR TREATMENT AREA ($)	EFFECTIVENESS 400 = TOTALLY EFFECTIVE	COST EFFECTIVENESS (x 100)	COST EFFECTIVENESS RANGE (x 100)
Straw @ 4000 lbs/acre	11.50-12.75 per 1000 sq ft	12/1000 sq ft	12.00	11.50- 12.75	319	3.8	3.6- 4.0
Grass Seed and Fertilizer	.93- 2.49 per lb	1.14 lb	9.89	9.45- 33.74	141	7.0	6.7- 23.9
Straw @ 8000 lbs/acre	23.00-25.00 per 1000 sq ft	24/1000 sq ft	24.00	23.00- 25.00	319	7.5	7.2- 7.8
Contour Trench	.34- 1.11 per ft	.36/ft	43.20	40.80- 133.20	200	21.6	20.4- 66.6
Hydro Seed (Theoretical)	40-80 (est) per 1000 sq ft	60/1000 sq ft	60.00	40.00- 80.00	(est) 270	22.2	14.8- 29.6
Wood Chips	80 - 110 per 1000 sq ft	95/1000 sq ft	95.00	80.00- 110.00	250	38.0	32.0- 44.0
Ravel Catchers	.70- 2.46 per ft	1.34/ft	66.76	35.00- 123.00	149	44.8	23.5- 82.5
Wooded Terrace	.53- 2.42 per ft	.59/ft	59.00	53.00- 242.00	125	47.2	42.4- 193.6
Jute w/straw @ 4000	181-281 per 1000 sq ft	230/1000 sq ft	230.00	181.00- 281.00	327	70.6	55.3- 95.9
Jute w/straw @ 8000	193-293 per 1000 sq ft	242/1000 sq ft	242.00	193.00- 293.00	327	74.2	58.9- 89.5
Wattles @ 6-foot spacing	.61- 2.95 per ft	1.46/ft	233.60	97.60- 472.00	158	147.8	61.8- 298.7
Wattles @ 4-foot spacing	.61- 2.95 per ft	1.46/ft	379.60	158.60- 1262.00	158	240.2	100.0- 485.4

APPENDIX B

Table 3 shows the relative cost effectiveness of check damming and hand rocking a 60-foot long channel with a gradient of 25%. For these comparisons, it was determined that nine check dams would be needed, each with an effective height of 1.5 feet, and that the rock should cover an area of 300 square feet (60 feet by 5 feet). This would insure adequate protection of side banks. The table contains the same categories as Table 2. Effectiveness was determined using the same method as before, except that only one criteria (the ability of the technique to prevent and/or control side cutting and downcutting) was used. All channels (including cross road drains) that were hand rocked or check dammed were included in the sample.

In conclusion, hand rocking of channels is both less effective and less cost effective than using check dams. Maintenance requirements of rocked channels is high the first few years, although the maintenance requirements of check dams may be higher overall. Total erosion over time for both techniques is probably about equal or perhaps more for check dams, since eventually they will fail and possible cause water to be diverted into channel banks.

Rocking with heavy equipment is probably more viable than hand rocking, although more than half of the heavy equipment rocked channels underwent fairly substantial channel adjustment. These channel adjustments may be avoided in the future through proper rocking techniques, such as excavating the channel bottom wide enough to contain peak flows and using a heterogenous mixture of rock.

It is difficult to say which technique is preferable at the present time and more studies should occur, mainly the trial check damming of large streams and the quantitative assessment of changes occurring in properly rocked channels.

TABLE 3

COST EFFECTIVENESS TO CONTROL CHANNEL EROSION IN A 60-FOOT LONG CHANNEL WITH A 25% GRADIENT

TECHNIQUE	COST RANGE (IN DOLLARS)	AVERAGE COST PAID IN PARK (IN DOLLARS)	WEIGHTED AVERAGE COST FOR TREATMENT (IN DOLLARS)	COST RANGE FOR CHANNEL TREATMENT (IN DOLLARS)	EFFECTIVENESS (100 = TOTALLY EFFECTIVE)	COST EFFECTIVENESS (x 10)	COST EFFECTIVENESS (x 10)
CHECK DAMS	20.40 - 45.00/ea	35.51/ea	319.59	183.78 - 409.00	88	36.3	20.9 - 46.5
ROCKING	.48 - 1.70/sq ft	1.23/sq ft	369.00	144.00 - 510.00	58	63.6	24.8 - 87.9

NEZPERCE ENGINEERING

FUNCTIONAL

MITIGATION PROCEDURES

TRANSPORTATION PLANNING

Review photos and delineate on base map

1. Wet areas (size)
2. Unstable ground (size)
3. Oversteepened ground (extent)
4. Noncommercial (extent)
5. Nonforested (extent)
6.

Review landtype classifications & maps and delineate on base maps

1. Problems
2. Management guidelines
3. Distinguishing features
4. Slope %
5. Area covered

Review topographic maps and highlight

1. Bogs
2. Slumps
3. Oversteepened ground
4. Stream channel geometrics
5.
    a. size
    b. channel form
    c. area drained
6. Aspect
7. Slope %
8.
9.

Review management plans & constraints & guidelines delineate controls

1. Multiple use plans
2. Unit plans
3. Wildlife, fishery, watershed, recreation, range, minerals, fire management, cultural
4. Legislative controls
    a. RARE II
    b. Wilderness Acts
    c.

Establish base map with above highlighted - locate proposed routes to fully service ground, while minimizing roading on

1. Creek crossings
2. Traversing above listed highlighting constraints
    a. wetlands
    b. oversteepened ground
    c. unstable ground
    d. visual controls
    e. cultural sites
    f. critical soil types
    g. recreation impacts

TRANSPORTATION PLANNING (continued)

Evaluations of roading ---

1. Least soil & water impact
2. Least cost
   a. haul
   b. constr.
   c. reconstr.
   d. maintenance
   e. logging systems
3. Fish & wildlife management controls

Specialist review & comments for concerns and mitigation ground controls

All above is incorporated in ATP & EAR processes

LOCATION

Review transportation planning and establish base map with called controls, constraints, and mitigation.

Reconnaissance

Review planning controls and establish ground controls. Reviewing

1. Stream crossings & stream conditions
2. Unstable ground
3. Wet lands
4. Logging breaks
5. Total system transportation plan (future entry)
6. Soil types, aspect & slope
7. Wildlife, range, recreation uses
8. Cultural sites

Establish road location criteria form (see enclosure I)

Tag Line

Locate a rough road grade between system and area controls, eliminating, and/or minimizing impacts on

1. Soil - water
   a. grades
   b. length in stream courses
   c. location on slope
      attempt to self balance
      cut & fills
   d. avoiding wetlands, unstable & oversteepened lands
   e. avoiding cultural, recreational & high visibility sites
2. Cost efficiency
   a. road geometric controls
   b. logging system demands

Final location

1. Places geometric controls with horizontal and vertical alignment
2. Recommend design standards
   a. rock blankets & filter cloths
   b. rock abuttress
   c. drainage placements
   d. stream channel mitigation
      (1) down spouts, fill height, riprapping, sheathing, down drains, velocity reduction
3. Soil classification for base stabilization, ditch line stabilization, or special base treatment -- highlight specialist review needs for review and design recommendation
4. Stream channel condition classifications
5. Clearing requirements
   windrowing for soil movement blocks
   burial (where not allowed due to land forms)

LOCATION (continued)

6. Transportation needs
   landings, turnouts, spurs, future roading, turnarounds, logging controls, potential recreation needs
7. Outline and highlight unstable, wet, wildlife high use areas, range uses, logging control problems, cultural resources areas for specialist review, recommendation and mitigations.
8. Review with land manager final location and establish a route final design criteria & location report
   This phase reviews --
   - Forest Transportation Plan
   - Area Transportation Plan
   - Environmental Assessment
   - Specialist recommendations

   and sets final road design controls. (see enclosure II)

DESIGN INFORMATION

Date: ____________________

Road Name and No.: ______________________________

Timber Sale Name: ______________________________

District: ______________________________

Road Standard: S________mph or D________mph Design Vehicle____________

New Construction__________miles Reconstruction__________miles

Design Data:

A. Roadway

1. Road Template

X - SECTION SUBGRADE

2. Ditch: Yes _____, No _____, Sections ____________________

3. Graveled: Yes _____* No _____

*Depth Compacted

4. Maximum grade favorable: Sustained____% Pitch____% Minimum grade____%

   Maximum grade adverse: Sustained____% Pitch____%

5. Minimum Radius of Curve: ______________________________ft.

6. Surfacing: Type: ______________________________
   Thickness: ______________________________
   Width: ______________________________

7. T.O. intervals ______________________________ft.
   Min. length of full width__________ft. Min. length of Transition______ft.
   Min. width of Turnout________ft.

8. Clearing width: Beyond Fill ______________________________ft.
   Beyond Cut ______________________________ft.
   Minimum Clearing Widths____________________ft. from centerline.
   Brush Bays Required____________________ Size____________________

   Clearing: Slash Treatment______________________________
   Method of Measurement______________________________

9. Remove Salvaged item to ______________________________ to be stockpiled.

10. Drainage
    Maximum distance between ditch relief ______________________________ ft.

    Identify sites requiring hydraulic structures (greater than 35 sq. ft., end area: ________________ Type structure recommended: ____________

    ____

    Have State agencies approved? ______ Is Site survey needed? __________

11. Fill widening: 0-5 feet _____ 5-10 feet _____ 10 feet plus _______________

    Crown _____% Super _____% In Slope _____% Out Slope _____%

    Curve widening = $\frac{\rule{3cm}{0.4pt}}{\text{Radius}}$ (See Curve Widening Tables to check on tight curves)

12. In what steep areas is sidecasting prohibited? _______________________

13. Excavation: Placement Method ____________ Tolerance Class ______________
    Slope Rounding ______________

14. Borrow Source
    1. Location of pit
       Township
       Range
       Section:
       MP Or MI to beginning of project:

    2. Pit development plan: (attachment)

    3. Rock Tests on Pit:

    4. Stock Pile Sites.

15. Seeding, fertilizing, mulching, and recommended mix:

    1. Kind ...... Quantity (lb/acre)
    2.
    3.
    4.

    Time of application _____________. Total lb. of seed per acre __________.

    Fertilizer ________%. Pounds per Acre ____________. 1st Application.

    Fertilizer ________%. Pounds per Acre ____________. 2nd Application.

16. Signs Required:

17. Identify stations where special structural provisions are anticipated (gates, cattle guards, bin walls, etc.): ______________________________

____

18. Will road be closed to public use during hauling? ______________
For special seasons of year? ______ At end of project? __________

19. Mitigating Measures: 1.) Rock Roads over ____% grades
2.) Rock Ditch Grades over ____%
3.) Rock Downdrains
4.) Curlex on live streams
5.) Filter windrows on Fills ________ft. high
6.) Length under Construction at one time _________.

20. Will road be barriered and "put to bed?"____, or drivable with gate? ____

Reasons for closure: ______________________________

____

21. Normal Construction Season ____________ to ________________.

22.a) Undeveloped campground sites to be preserved ________________

____

b) Trailheads to be preserved ______________________________

23. Right-of-way Data: R/W required ______________ plats completed ____
Corners to be protected ________________

24. Turn arounds a) At end of road __________

b) Maximum interval on roads _________

25. Landings or Landing Take-off Locations
Approximate Stations ______________________________

____

____

ENGINEERING REPORT

DESIGN CRITERIA

COMMENTS

District Ranger--

Forest Engineer--

Other--

DESIGN CRITERIA

ENGINEERING REPORT

____
Road Name and Number

____
(Project or Timber Sale Name)

____
(Ranger District)

NEZPERCE NATIONAL FOREST

Reviewed:	______________________ District Ranger	______________ Date
	______________________ Forest Engineer	______________ Date
	______________________ Sale Designer	______________ Date
	______________________ Road Designer	______________ Date
	______________________ Preconstruction Engineer	______________ Date

7. Engineering Criteria

D. Drainage
1.) Surfacing
a.) Rock
(type) ____________________
b.) Oil
(type) ____________________
c.) Other
(explain) ____
____
____

2.) Template
a.) Inslope
b.) Outslope
c.) Flat
d.) Other
(explain) ____
____

3.) Cross Drains
a.) Dips
b.) Culvert
c.) Other
(explain) ____
____

4.) Ditches Yes No
a.) Depth ________________
b.) Special
(explain) ____
____
c.) Inslope ratio ____________________________________

E. Clearing
1.) Above cut ____________________________
2.) Below fill ____________________________
3.) Min. from shoulder ____________________________
4.) Disposal Method
a.) Windrowing
b.) Windrow & cover
*c.) Scatter
*d.) Remove
*e.) Bury
f.) Chip
*g.) Pile & Burn
*h.) Disposal in cutting units
*Where: ____
____

F. Turnout Spacing
1.) Length ______________________
2.) Flare Length ________________

ENCLOSURE 1

ROAD LOCATION CRITERIA

1. Logging System to be used:

   A. Skyline
   B. Hilead
   C. Tractor
   D. Multispan

2. Equipment Size (Maximum) ______________________________

   ____

3. Future Entries:

	No. Entry	Volume
A. 5 year plan	________	________
B. 20 year analysis	________	________

4. Future Administration needs:

   A. Slash clean up
   B. Fire protection
   C. Silviculture
   D. Other (list) ______________________________

   ____

5. Season of use

   A. Winter
   B. Normal season (list dates) ______________________________

6. Transportation Plan Criteria

   A. Road class - Arterial _____. Collector _____. Local_____.Temp spur _____.
   B. Termini Begin______________ End________________

7. Engineering Criteria

   A. Alignment
      1.) Minimum Radii ________
      2.) Maximum Radii ________

   B. Profile
      1.) Maximum Grade ________
      2.) Minimum Grade ________
      3.) Maximum Pitch
          Favorable ________
          Adverse ________
   C. Roadwidth (finish) ______________________________

7. Engineering Criteria

   4.) Disposal Method cont.

   Exceptions (List)________________________________

   ____

   5.) Conserve for Filter Strip

8. Land Use Restriction (EIS or EAR)

   A. Visual Aspect________________________________

   ____

   B. Endangered or Rare Species
      1.) Vegetation________________________________

      ____

      2.) Wildlife________________________________

      ____

      3.) Fisheries________________________________

      ____

      4.) Historical________________________________

      ____

      5.) Archeological________________________________

      ____

   C. Soils ________________________________

   ____

   ____

   D. Geology (landform stability)________________________________

   ____

   ____

   E. Water ________________________________

   ____

   ____

   F. Fire Management________________________________

   ____

   ____

9. Road Closure Yes No
   Type: ________________________________

   ____

10. Unit Plan Complete Yes

11.. E.A.R. Complete Yes
   What date ____________

12. Location Completion date (est.) ____________________*

13. Location Approval Date from District Ranger's Review (est.) ________
(5 days after location completion)

A. Logging Engineer's Review* (est.) ______________________________*

*Should be same date--Logging Engineer's before.

14. Unit Marking color codes and/or stations ____________________________
____

15. Survey Crew camp areas and controls ______________________________
____

Pre-Location Meeting date _______________________________________

Locator: ____

District Representative: ____

Ranger: ____

Forest Engineer Representative: ___________________________________

DESIGN

1. Review location report, specialist recommendations, and final design criteria form.
2. Field reviews all criterial areas as outlined by locator and/or specialist and collects additional information as needed.
3. Reviews Environmental Assessment
4. Attaches copy of all recommendations and classification notes to traverse and grade plots
5. Reviews standard specifications for project need and writes special project specifications as needed to meet mitigation controls (see spec. 204, enclosure III)
6. Designs roadway utilizing horizontal-vertical controls located by transportation systems (enclosure IV). Manipulates these controls to obtain the least impact roadway
    a. minimum cut & fills which is the major land impact
    b. designs drainage stability and other features to obtain specialist recommendations.
    c. grades (soil stability) (see enclosure V)
7. Incorporates spec. 204 (enclosure) to accomplish land management mitigation needs.
8. Reviews design procedures and results to obtain the most cost efficient system while mitigating land impacts as specified by various specialists.
9. Final design is reviewed by locator, land manager and specialists involved during previous stages. This entails office and field review.

SECTION 204 - SOIL EROSION AND WATER POLLUTION CONTROL

DESCRIPTION

204.01. This work shall consist of special temporary and permanent construction measures as SHOWN ON THE DRAWINGS and/or listed in this specification to control soil erosion and water pollution. Such measures may include (but are not limited to) slash windrows, brush barriers, drainage devices, earth berms, sediment basins, aggregate base/surfacing, rock ditches, riprap, seeding, netting, and/or straw bales.

This work shall also include special construction methods SHOWN ON THE DRAWINGS to control erosion at control areas.

MATERIALS

204.02. Materials shall meet the requirements of the following subsections:

Emulsified Asphalt..............................702.03
Agricultural Limestone..........................713.02
Fertilizer......................................713.03
Seed..713.04
Mulch...713.05
Net Material....................................713.07
Woven Plastic Filter Cloth......................720
Nonwoven Plastic Filter Cloth...................721

All other materials shall meet commercial grade standards and shall be approved before being incorporated into the project.

CONSTRUCTION SCHEDULE

Prior to the start of construction, the contractor shall submit a schedule for proposed erosion control work. The schedule shall include all applicable items listed in Table 204.1 of this specification and any other work necessitated by the proposed construction methods. The schedule shall consider erosion control work necessary for all phases of the project including aggregate sources, borrow and waste areas, and haul roads. The contractor's construction schedule and plan of operation will be reviewed in conjunction with the erosion control plan to insure their compatibility before any schedules are approved. No work will be permitted on the project until all schedules have been approved by the engineer.

Erosion control features shall be incorporated into the project no later than the dates specified in Table 204.1. Variations in this schedule must be approved in writing by the engineer.

CONSTRUCTION REQUIREMENTS

204.03

a. EARTHWORK. Excavation, borrow, and embankment operations shall be scheduled and performed so that permanent erosion control features can be installed or constructed within the time periods listed in 204.1.

b. STREAM COURSES. Temporary culvert installations will not be permitted in live streams unless approved individually in writing by the engineer. If such approval is granted, temporary culverts shall be offset a sufficient distance so that installation of the permanent culvert can be completed without removal of the temporary culvert. Temporary culverts shall not be removed until flowing water is completely confined to the permanent culvert.

Diversion of live streams to allow work in the streambed shall be performed in such a manner as necessary to prevent erosion. Dikes of sufficient height to divert the flow without being overtopped shall be constructed in the stream above the drainage structure. Water shall be conveyed around the work area by a non-eroding conduit. Watertight pipes, tubing, or lined trenches may be used. Trench or pipe outlet areas shall be protected with plastic or other material approved by the engineer to insure that diverted water does not cause erosion as it returns to the stream.

Equipment shall not be operated in the stream unless authorized by the engineer. This does not include a one time crossing of the stream to begin installation. After installation of the permanent drainage structure is completed all dikes, basins, and trenches shall be removed and the area restored to near natural condition.

c. WET CONDITIONS. The contractor shall, at all times, conduct operations to minimize erosion and prevent development of conditions that will cause erosion. Work may continue during wet conditions as long as erosion and rutting is controlled.

d. END OF CONSTRUCTION SEASON. Prior to move-out, any rutted areas and other damaged areas shall be smoothed, sloped, and graded to drain and all erosion control features required under this specification shall be functional and approved by the engineer.

e. MAINTENANCE. All erosion control features shall be maintained by the contractor throughout the period of construction.

METHOD OF MEASUREMENT

204.04. The method of measurement will be DESIGNATED IN THE SCHEDULE OF ITEMS and measured in accordance with section 106. Items not shown in the Schedule of Items will not be measured.

BASIS OF PAYMENT

204.05. The accepted quantities will be paid for in accordance with section 106 at the contract unit price for each pay item shown in the SCHEDULE OF ITEMS.

Payment will be made under:

	Pay Item	Pay Unit
204(01)	Temporary Seeding and Fertilizing	Acre
204(02)	Mulching	Ton
204(03)	Asphaltic Material	Gallon
204(04)	Chemical Soil Stabilizer	Gallon
204(05)	Temporary Netting	Square Yard
204(06)	Straw Bale	Each
204(07)	Gravel Blanket	Cubic Yard
204(08)	Silt Fence	Linear Foot
204(09)	Brush Barrier	Linear Foot
204(10)	Fiber Glass Roving	Pound
204(11)	Sediment Basin	Each
204(12)	Berm	Linear Foot
204(13)	Dike	Linear Foot
204(14)	Dam	Each
204(15)	______________ for Soil Erosion Pollution Control	Each
204(16)	______________ for Soil Erosion Pollution Control	Linear Foot
204(17)	______________ for Soil Erosion Pollution Control	Square Yard
204(18)	______________ for Soil Erosion Pollution Control	Acre
204(19)	______________ for Soil Erosion Pollution Control	Cubic Yard

Other erosion control work required under this specification and not shown on the Schedule of Items is considered incidental to the item number listed in Table 204.1.

TABLE

Item No.	Applicable To This Contract Yes/No	Duration	Description of Work	Timing of Construction
201( )		Permanent	Mandatory Slash Windrows in locations shown on the drawings.	At time of pioneer road construction at live streams. Within ___ days of pioneer road construction in other areas.
Incidental to to 201( )		Permanent	Waterbars on Slash Burial Pits Maximum spacing _____ feet (slope distance)	Constructed continuously as pits are backfilled
203( )		Permanent	Culvert Catch Basins and Ditch Transitions	Continuously with culvert installation.
203( )		Permanent	Inslope/Outslope/Crown as shown on drawings	Continuously as road is roughed to grade.
203( )		Permanent	Ditches	Within ____ days of roughing to grade. Within ____ days after ________. (date)
Incidental to 203( )		Temporary	Earth Berms (min. 1 foot high) on shoulder(s) of road in fill areas as directed by the engineer. Earth berms to be bladed back and incorporated into road subgrade.	Maintain continuously all areas roughed to grade until gravel surfacing is placed.
Incidental to 203( ) or 209( )			Special Construction Methods Specific locations and requirements shown on the drawings.	As described on the drawings.

TABLE 204. (cont'd)

Item No.	Applicable To This Contract Yes/No	Duration	Description of Work	Timing of Construction
Incidental to 203( )		Temporary	Waterbars in all areas of disturbed earth. 1. In areas not roughed to grade or without completed permanent drainage features: *Max spacing 100 ft. for road grades over 12% *Max spacing 200 ft. for road grades 8 to 12% *Max spacing 300 ft. for road grades under 8%	Maintain continuously in all areas until gravel surfacing is placed.
			2. In areas where permanent drainage features are completed:	
			*Within 20 ft. uphill of all culverts, except in through fill areas.	Continuously
			*Within 20 ft. uphill of the start of through fills.	Continuously
			*Approximately halfway between culverts, except in through fill areas as needed to control erosion during periods of winter shutdown.	Maintain continuously in all areas that are not gravelled after ________. date
203(18)		Permanent	Drainage Dip Locations shown on the drawings.	Prior to the end of the construction season for all areas roughed to grade.
Incidental to 203( )		Temporary	Straw Bales/Straw Mulch Locations shown on the drawings or as necessary to stabilize eroding areas.	Immediately upon discovery of active erosion.
203( )		Temporary	Pioneer Roads The total length of all pioneer roads shall not exceed ______ lineal feet after ________. date	See description of work

Item No.	Applicable To This Contract Yes/No	Duration	Description of Work	Timing of Construction
204(09)		Permanent	Brush Barriers Locations shown on the drawings.	Within ___ days of culvert installation in live streams. Within ___ days of fill construction in other areas.
204(11)		Permanent	Sediment Basins Locations shown on the drawings.	Prior to culvert installation.
209(01)		Permanent	Rock Blanket Locations shown on the drawings. Note: Additional restrictions may be imposed under Special Construction Methods above.	Prior to crossing the planned location if designated rock source is accessible. Within ___ days of pioneer road access to rock source if source is beyond rock blanket location.
304( )		Permanent	Aggregate Base/Surfacing The total length of all areas of disturbed earth (including pioneer roads and completed subgrades) on which gravel has not been placed shall not exceed ______ lineal feet after __________ (date). This requirement may be waived by the engineer based on a review of the contractor's operations, methods, and progress in controlling erosion and keeping erosion control features current as described in this specification. Such waiver, if given, shall be in writing.	See Description of work.

TABLE 204. nt'd)

Item No.	Applicable To This Contract Yes/No	Duration	Description of Work	Timing of Construction
304( )		Permanent	Rock Ditch	Completed in all areas roughed to grade by ________ (date). Within ___ days of subgrade completion after this date.
603( )		Permanent	Culverts	
			*Live Streams	At time of initial crossing of live streams.
			*Cross Drains	Maximum of ______ lineal ft. of road roughed to grade without culverts after ________ (date).
607( )		Permanent	Road Closure Devices	By ________ on all areas designated for this work item and roughed to grade.
619( )		Permanent	Culvert/Inlet/Outlet Riprap	Within ______ days of culvert installation in live streams; by the end of construction season in other areas.
619( )		Permanent	Cut Slope Drains	Within ______ days of pioneer road crossing of live stream.
619( )		Permanent	Fill Slope Drains	By ________ (date) in all areas roughed to grade. Within ______ days of all fill construction after this date.
619( )		Permanent	Rock Buttress	By end of construction season in all areas, unless otherwise noted on drawings.
619( )				
625(05)		Permanent	Seeding	Maximum of ______ lineal feet of road(s) unseeded after ________ (date). Maximum of ______ lineal feet of road(s) (including pioneer roads) unseeded at end of construction season.
625(12)		Permanent	Netting	Completed in all roads roughed to grade at end of construction season.

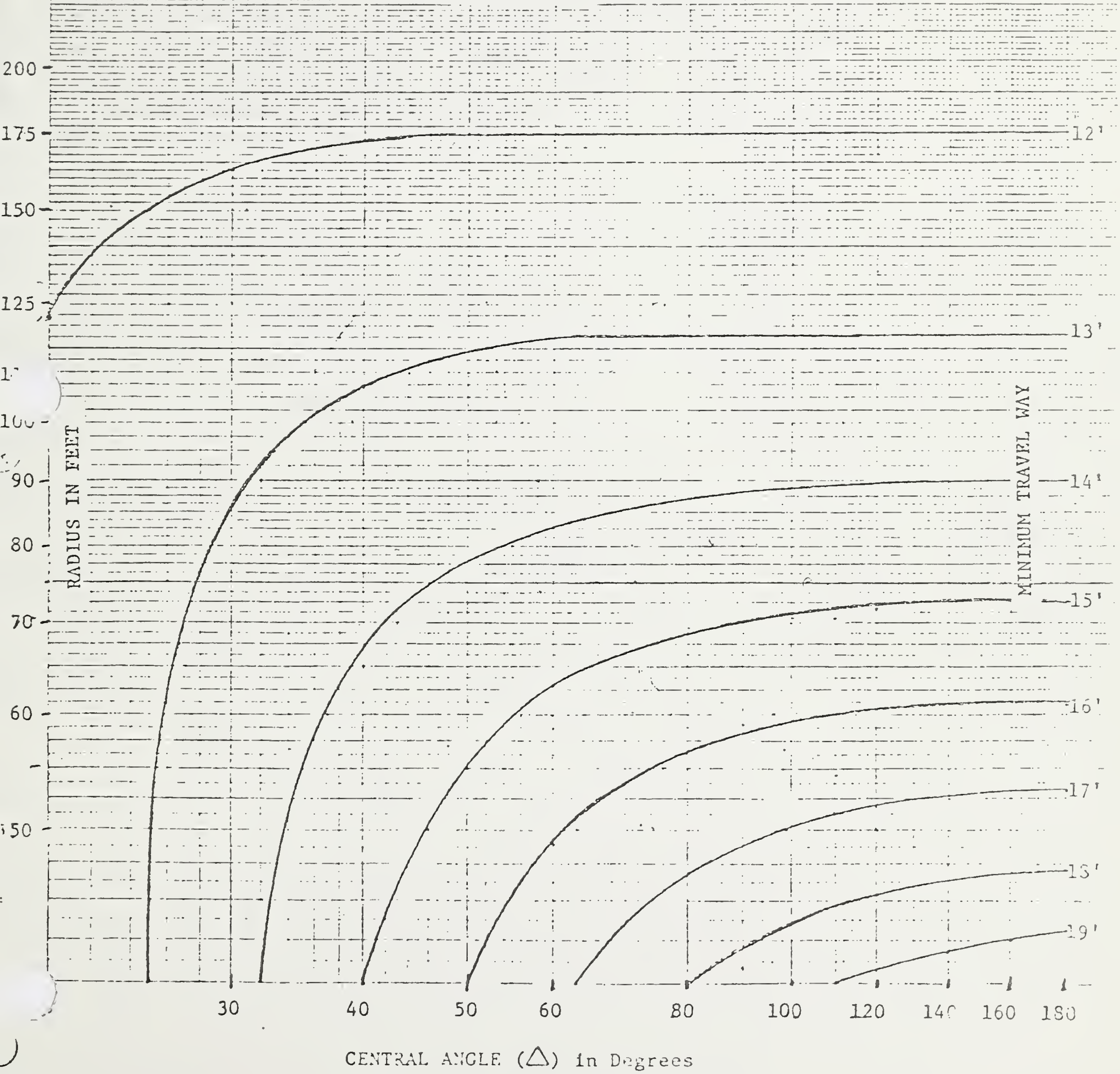
15 Finish top
12 Finish top
3

MINIMUM TRAVEL WAY

for

LOG TRUCK WITH A 20' TRACTOR,

10' STINGER, AND 30' BUNK TO BUNK



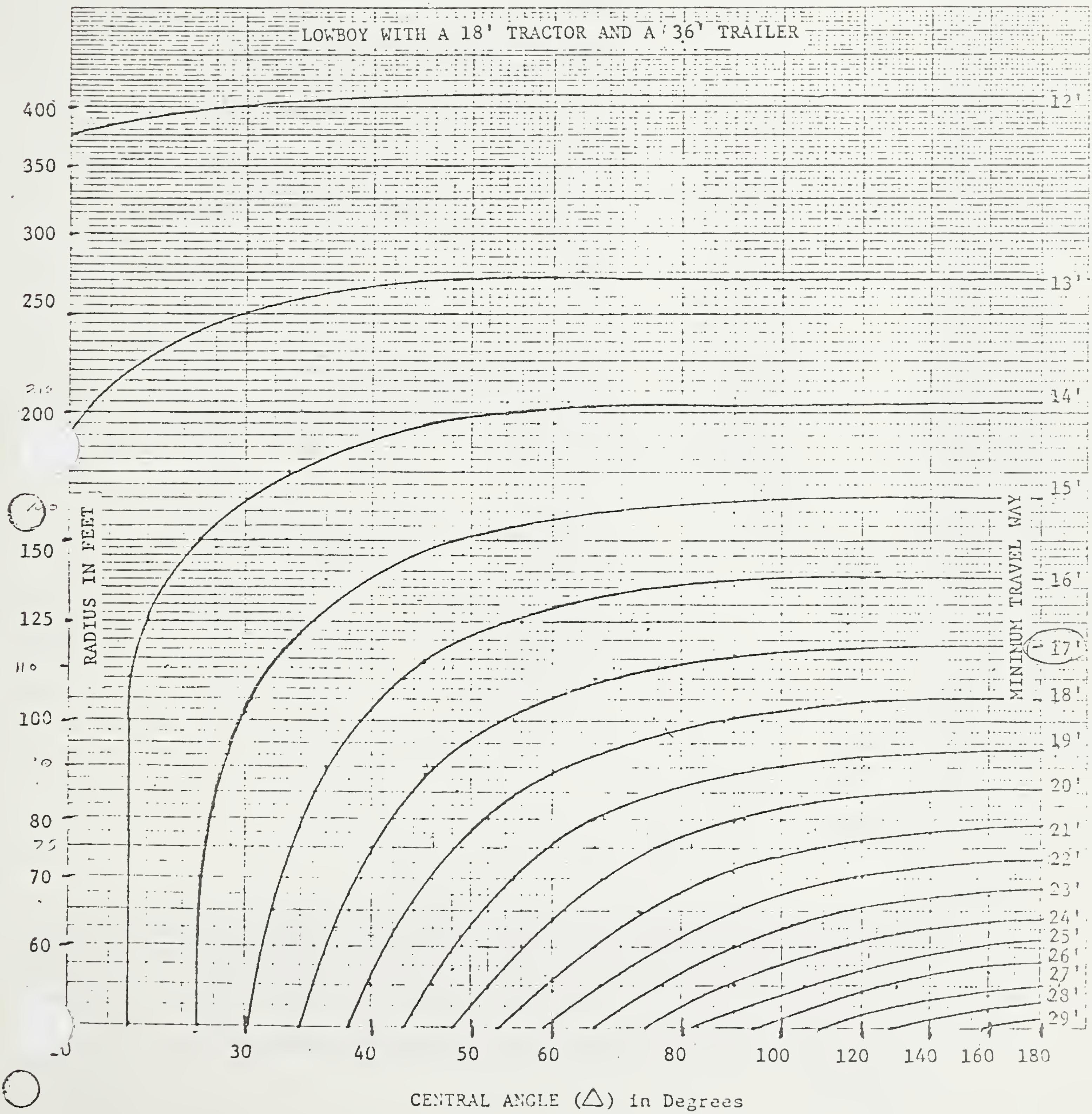
12
14

17
12
5

MINIMUM TRAVEL WAY

14
5
19

for



ENCLOSURE V

CROSS DRAIN SPACING GUIDE - NEZPERCE NF
Maximum Cross Drain Spacing For
Erosion Control in Silty Sand Soils
Granitic or Gneissic Rock Derived

Sustained Road Grade %	Bare Soil (ft)	ROCK DITCH		
		Crushed Rock (ft)	Min. Ave. Rock Size For** 500 ft. Max. Cross Drain Spacing	
			Grade (%)	d50 (in)
2	305*	--		
3	305*	--	5-6½	½
4	305	--	6½-7½	3/4
5	245	--	7½-8½	1
6	205	--	8½-9½	1½
7	175	515	9½-10½	2
8	150	450	10½-11½	3
9	135	400	11½-12½	3½
10	120	360	12½-13½	4
11	110	325	13½-14	4½
12	100	300	14-15	5½
13	95	275		
14	90	255		
15	80	240		

*For Drainage
**For Pit Run Rock In Ditch

CONSTRUCTION

1. Meet with contractor prior to start of work to review general contract requirements and answer questions.
2. Review contractors proposed plan of operation, schedule, and erosion control plan to identify potential problems that may result from the construction operations.
3. Check staking of project for compliance with accuracy and format requirements specified in the contract. Also, try to identify problem areas in advance of actual construction to be sure that project can be built as designed.
4. Administer contract to obtain compliance with drawings, standard specifications, and special project specifications.
5. Modify the original design as needed to meet the original design objectives in the face of conditions not foreseen at the time of the original design.
6. Monitor construction and restrict operations if necessary to control erosion.
7. Install straw mulch or bales to control minor erosion areas.
8. Arrange final inspection at completion of project with assistance of Forest Engineer, Assistant Engineer and District Ranger.
9. Write final construction report for projects in excess of $500,000

MAINTENANCE

1. Review EA and Area Transportation Plan
2. Coordinate with Ranger District and Transportation Plan for rotating maintenance schedule based on
    a. A.D.T.
    b. road closures
    c. logging schedules
3. Monitor maintenance and minor reconstruction and restrict operations as needed to control erosion.
4. Re-seed roads or portions of roads as needed to prevent & control erosion.
5. Coordinate with Geotechnical Section on slide and slump removal and repair, to cause the least amount of resource damage.
6. Install additional drainage structures as needed to reduce erosion.
7. Maintain the road surface and ditch in such a manner as to remove the water from the roadway as quickly as possible.

CHART I

CROSS DRAIN SPACING GUIDE

NEZPERCE NATIONAL FOREST

MAXIMUM CROSS DRAIN SPACING
FOR EROSION CONTROL IN
SAND SOILS - GRANITIC OR
GNEISSIC ROCK DERIVED

Sustained Road/Ditch Grade (%)	Bare Soil (ft)	Crushed Rock (FE)
2	615	---
3	410	---
4	305	---
5	245	---
6	205	---
7	175	515
8	150	450
9	135	400
10	120	360
11	110	325
12	100	300
13	95	275
14	90	255
15	80	240
16	75	225
17	70	210
18	65	200
19	65	190
20	60	180

Crushed rock includes rock down to 1" minus rock (Grading D).

CHART II

REQUIRED ROCK SIZE BY GRADE FOR A 500 FT. MAXIMUM CROSS DRAIN SPACING

Sustained Ditch Grade (%)	Average Rock Size d_{50} (in)
5 - 6½	½
6½ - 7½	3/4
7½ - 8½	1
8½ - 9½	1½
9½ - 10½	2
10½ - 11½	3
11½ - 12½	3½
12½ - 13½	4
13½ - 14	4½
14 - 15	5½
15 - 16	6½
16 - 17	7½
17 - 18	9
18 - 19	10½

Chart Based On: Critical velocity of 6º ft/sec.

$$S_o = \left(\frac{6\,[illegible]\,n}{0.54}\right)^2$$

$$n = 0.0395\, d_{50}^{\;1/6} \text{ (Approximate)}$$

Library

FOREST SERVICE MANUAL
Kalispell, Montana

March 1983

TITLE FSH 7709.11 - TRANSPORTATION ENGINEERING HANDBOOK

Flathead NF Supplement No. 1

POSTING NOTICE. Supplements to this title are numbered consecutively. Post this supplement behind the blue pages. Check the last transmittal received for this title to see that the above supplement number is in sequence. If not, order intervening supplements at once on form 1100-6. Do not post this supplement until the missing one(s) is received and posted. After posting retain this transmittal until the next supplement to this title is received. Place it at the front of the title.

Page Code	Superseded	New
	(Number of Sheets)	
24.4--1 thru 24.4--5	0	3

Digest:

Sets general guidance for drainage erosion control in design and some key design techniques.

FOR JOHN L. EMERSON
Forest Supervisor

24.4 - Roadway Drainage. To be fully effective and cost efficient, design of drainage and erosion control features must start with location and be consciously included in considerations continuing through plans-in-hand and contract preparation. Incorporation as an independent step late in the design process is inadequate. Design shall culminate in the preparation of contract plans, provisions, and specifications which adequately provide for the soil and water resource concerns identified by field reconnaissance or planning documents.

General Guidance for Drainage and Erosion Control in Design

1. Drainage and erosion control features can generally be included on standard plan and profile sheets. Large or particularly complex projects may require preparation of a separate set of erosion control plans.

2. Existing and potential stability problems must be identified and provided for as an initial design step. It is often advantageous to resolve these situations before proceeding to the overall design.

Most design changes and change orders, with their attendant impact on project and construction engineering costs, are initiated for purposes of correcting previously unidentified stability oriented failures. Frequently, these problems critically influence erosion rates. It is expected that all reasonable steps consistent with FSM 7720.31 and 7721.22 be taken to limit such occurrences and thereby reduce unanticipated soil loss.

3. Application of the dry basement theory is nearly mandatory if sedimentation is to be held within tolerable limits. This means sufficient subsurface drainage must be provided to assure a stable subgrade during anticipated periods of use. Sufficient vertical separation between ditch or drainage structure invert and centerline grade to permit development of load bearing capacity and avoid piping damage is essential.

4. The designer must be aware of the significance of his acts. A primary hazard in design is the taking of a routine approach. This is particularly applicable to erosion control. In extreme cases, for whatever cause the designer

alone can be responsible for originating more soil loss and damage than from all other sources combined. Plan reviews do not always pinpoint errors in technique or judgement. If undetected, the end product frequently not only unduly contributes to resource degradation but also fails to fully serve its intended purpose.

5. Plan ahead for increased runoff where management prescriptions call for significant reduction in ground cover above a planned facility. This is particularly important if the cover loss is to occur early in design life. Also investigate the need for control measures to offset loss of ground cover below.

6. Too many cross-drains are preferred to too few. It must be recognized, however, that there is a point of practical return in their spacing. On steeper grades in finer grained soils, it may be impossible to space them closely enough to prevent rilling in the ditchline. In such cases, a realistic spacing based on Q with intervening ditch stabilization is more appropriate. Generally, when spacing is reduced to the 150 to 200 foot range it is cheaper to reinforce the ditch. A cost analysis of the individual case is required to arrive at a break-even point.

7. There is no long-range benefit to designing cuts and fills steeper than the angle of repose of the soils from which constructed. Cuts are more critical than fills since the bulk of soil movement originates there and, once in motion, sediment is more apt to reach water courses. Particularly where erosion potential is moderate or high, finding an alternative to oversteepened cuts has top priority. In addition to the other negative aspects, the success ratio of stand establishment effort in such instances is very poor.

8. Much of our construction involves self-balanced dozer side-casting. Due to lack of compaction and relatively low placement efficiency, potential for soil loss is generally higher than for other placement methods. Consequently, as an absolute minimum, offsetting control measures are to be provided at and adjacent to streams when constructing by side-casting.

9. Design is one of several transportation system development and management phases. Construction, use, and maintenance follow. Each contributes to the overall sediment

situation. It makes little sense to call for extensive mitigating measures in design if benefits are to be lost in the process of constructing, operating, or maintaining the facility. Likewise, the cumulative impact over time of each significant design decision needs to be assessed before becoming final. A classic example is the often faced dilemma of whether better to pull the gradeline into incised draws to effect stream crossings or to cut the nose off of ridges on either side of drainages and through-fill across them. Traditional thinking favors minimizing cuts and fills by pulling alignment into the draws to minimize disturbance. This is not always the best, however, when the total erosional impacts of operating over and maintaining the additional roadway (much of it parallel to and just above the stream on both sides) are taken into account. Situations such as this where compromise in the design phase may yield more effective long-term results need to be identified and included in the process.

10. Attempt to call for control measures which utilize natural materials and can be left in place at project completion. Their removal allows trapped sediment to return to motion. Requiring removal generates unnecessary added expense and new disturbance. Over time natural materials blend into the background and are more esthetically acceptable.

11. Ditch scour is sufficiently common and its impact on water quality great enough to warrant direct, conscious attention being paid to this factor. If washing of the ditchline is apt to ultimately require corrective treatment under maintenance, the situation might better be dealt with during design and the degrading effect of generated sediments prevented.

12. Typically, whether roads are open or closed, the leading contributor to soil loss is the roadway surface. About the only practical way of retaining subgrade fines on surfaces expected to sustain traffic is to cover them with coarser material. It serves as a filter, provides velocity reducing roughness, resists tractive forces, provides needed strength to resist rutting and reduces dusting. Therefore, considering the grades and soils frequently dealt with, there may be no alternative to calling for surfacing if erosion prevention is an important factor. A special case alternative for intermittent service roads may be cover establishment full-width.

13. A wide range of control devices are available (i.e., check dams, silt fences, plastic ditch liners, etc.), for specialized situations. When warranted, it is intended they be used. If thoughtfully integrated with other project work they can be incorporated at modest expense and very effective.

14. Do not overlook the impact of extremely fine grained materials held in suspension in moving water. The value of sedimentation ponds and settling basins in reducing suspended solids is significant.

15. Recognize the hazards associated with insloping and outsloping. Soil composition, grade, precipitation, and runoff conditions as well as season of use can be critical to their success. In both cases, rutting of the traveled way can seriously reduce or eliminate effectiveness. Insloping is counter to prevention guidance since it does not get flow off the facility by most direct means, the traveled way doubles as a drainage structure, and crowding of flow to bottom of cut promotes saturation of subgrade full-width. Similarly, although meeting dispersal by most direct means guidance, outsloping directs runoff to raw fill slopes in an uncontrolled manner, whether susceptable to washing or not and without regard for length of slope involved. It is important that each field situation stand on its own. A surface drainage method is to be selected which accomplishes established use objectives with a minimum of soil loss.

Some Key Design Techniques

1. Attempt to low point sag vertical curves at points of minimum fill and as close to undisturbed earth as possible. Avoid low pointing in the middle of through fills if at all possible.

2. Avoid sustained grades. Also avoid grades flat enough to promote ponding on the roadway and in ditchlines. Provide frequent opportunity for water to leave the roadway. Attempt to locate these at daylight points and outlet to undisturbed earth. If possible, roll grades. This, more than anything else, helps disperse surface water.

3. Skewed cross-drains, especially when they offer opportunity for outletting onto stabler ground or eliminating "shot-gunned" outlets, are a bargain. In the typical single lane situation, a 60 degree skew increases cross-drain costs

less then 5 percent. Skews less than 60 degrees are not recommended.

4. Unless suitable energy dissipation is provided, avoid outletting culverts above natural groundline. Culvert grade should be about two percent greater than inlet ditch grade to prevent plugging and loss of the culvert and/or roadway. It should be as little over that as possible, however, if scour at the outlet is to be minimized. Particularly when on steeper grades or in fine grained soils, reinforce drainage outlets. Rough reinforcement materials are preferred since they also serve to reduce velocity and dissipate energy.

5. There may be occassional opportunity for the appropriate use of berms. Whether constructed accidentally or on purpose, however, generally berms are to be avoided. They concentrate flow on the roadway, are prone to failure (frequently at the point of greatest erosion hazard), and promote saturation of the subgrade.

6. Particularly when placed under controlled conditions for the expressed purpose of serving as a sediment trap, one of the most cost effective control devices is a windrow of fine brush and clearing debris keyed into the toe of erosive fill slopes. Therefore, under appropriate field conditions, Clearing Method 1 can offer advantages. Windrow and cover, on the other hand, is not advocated since it tends to promote rather than control erosion.

7. Another relatively inexpensive control measure is use of hay or straw bales staked down firmly at the toe of slopes, around culvert entrances and/or outlets or used as temporary ditch checks. As with windrowing, this approach has particular application adjacent to live streams.

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TITLE 7700 - TRANSPORTATION SYSTEM

Flathead NF Supplement No. 9

POSTING NOTICE. Supplements to this title are numbered consecutively. Post this supplement behind the blue pages. Check the last transmittal received for this title to see that the above supplement number is in sequence. If not, order intervening supplements at once on form 1100-6. Do not post this supplement until the missing one(s) is received and posted. After posting retain this transmittal until the next supplement to this title is received. Place it at the front of the title.

Page Code	Superseded (Number of Sheets)	New (Number of Sheets)
7706.1	-	1
7710.31	-	1
7721.54	-	1
7732.02	-	1

2P 4-15-83

Digest:

7706.1 - Sets overall sediment control policy for Forest Transportation System.

7710.31 - Provides erosion prevention direction to transportation planning.

7721.54 - Erosion prevention and control direction for construction engineering.

7732.02 - Objectives for erosion prevention and control in Transportation System Operation and maintenance.

JL Emerson

JOHN L. EMERSON
Forest Supervisor

7706.1 - Resource Coordination. Sediment control policy for the Flathead National Forest transportation system is as follows:

1. Erosion prevention is to be stressed over sediment control and stabilization.

2. Some unintended soil movement is an inevitable consequence of development and operation. Forest objectives shall be twofold:

a. To limit disturbance to the minimum commensurate with resource management requirements, economic viability, and sound engineering practice; and

b. To trap and/or permanently stabilize soils subject to movement at or as near point of origin as opportunity permits.

3. Degree of emphasis required for erosion control shall be included in transportation planning documents or environmental assessment. This emphasis shall be reflected in the design criteria for all projects. When need is identified, a formal erosion control plan shall be prepared and approved by the District Ranger and Forest Engineer. Provisions of design criteria or erosion control plans shall be incorporated in the subsequent contract(s) for construction.

4. Operations and maintenance generated prevention and control requirements are to be identified by timely condition surveys and included on maintenance schedules. Extent and promptness of response shall be dependent on magnitude and seriousness of the particular situation and on the availability of corrective resources. Priority for remedial action shall be not less than that for keeping needed transportation facilities functional and available for use.

5. Control measures shall be considered to have failed when they do not prevent materials subject to streambed deposition from entering the first identifiable natural watercourse.

6. Emphasis shall be on selecting simple, inexpensive control measures which capitalize on natural processes and may be left in place.

7. It is intended that where practical, control measures provided to mitigate construction related disturbance be designed to also accommodate local, naturally occurring sediments intercepted along the route. This is required if the long term integrity of the facility is in question.

7710.31 - Transportation Plans. Transportation planning constitutes the foundation of transportation system development. It generally is the most critical step in the development process. This applies as fully to erosion prevention and sediment control as to any other functional feature of a transportation facility. Emphasis must be placed on prevention and control in the planning effort.

1. The planning process is the point at which resource development and management conflicts are to be resolved (on an interdisciplinary basis). If necessary, this is where acceptable compromises must be reached.

2. Resource protection is a primary concern. Intent is to assure that degradation associated with developmental activity is held within predetermined acceptable limits. If it cannot be reasonably assured, protection takes precedence over development.

3. Sound resource stewardship mandates stressing prevention as the first option. If impossible to achieve both management and prevention objectives, suitable control measures must be included during the development of alternatives.

4. Since mitigation is an additional developmental expense, pressure to minimize access costs favors prevention.

5. Planning and location are the most critical transportation system activities in achieving the prevention objective. If not provided for at this level, design and construction phases are largely locked into providing control.

6. Analysis and documentation of prevention/control impacts and costs are required in transportation plans and project development documents. It is intended that degree of thoroughness be in proportion to the sensitivity of the soil and watershed situation within the area involved.

7. Appropriate resource data and specialist assistance are to be utilized early in the planning process to identify and avoid potential problems.

8. The objective for prevention is to capitalize on every opportunity for reducing soil loss by influencing the factors in the equation to which it responds. Since total prevention is impossible, it must be recognized that the cost and effectiveness of mitigation are heavily influenced by these same factors.

9. Objective for control is to permanently stabilize soils subject to movement prior to their reaching active natural drainages. This constitutes the general limit for what may be considered tolerable degradation.

10. In recognition of the difficulty in effectively dealing with silts and clays, where they comprise a significant portion of representative soil samples, extra investment in prevention is appropriate.

7721.54 - Construction Engineering, Supervision, and Inspection. The best of planning and design is of no value if not translated into positive action. Construction and reconstruction, with its attendant inspection and control, is the developmental phase in which this action must occur. Stated below is erosion control direction for construction activities applicable to the Flathead National Forest. It applies whether work is accomplished by timber purchaser, public works contract, force account, cooperator, or via special-use permit. The engineer in charge of project construction (ER, COR, etc.) shall be responsible for taking the following actions as applicable:

Prework:

1. Become thoroughly familiar with provisions of the project EA and site conditions and potentials. Anticipate what might be reasonably expected in terms of climatic events and soils responses during the life of the project and the life of the facility being constructed.

2. After a jobsite assessment, review project plans and specifications for adequacy in providing for erosion prevention and sediment control.

3. Arrange to include any provisions which may have been missed in project preparation.

4. Cover prevention and control as a distinct topic at the Prework Meeting. Secure assurance that contractor's representatives understand prevention/control requirements and their purpose.

5. Require the contractor's intentions for implementing prevention control measures be included as a part of his Operating Plan. Incorporation of a specific Erosion Control Plan as a part of the Operating Plan may be required if warranted.

6. Hold a short jobsite meeting with the work force for purposes of familiarizing them with measures and techniques applicable to the project prior to start of work.

Project Work:

1. See that specified work is completed in a timely manner. Promptness and the effectiveness of control measures is frequently more important than meeting the letter of technical requirements. Weather has a way of changing drastically overnight and adverse periods can last for weeks. Establishing and enforcing reasonable limits to amount of

disturbance permitted before installing control measures is important.

2. Stay alert to unanticipated site condition changes or contractor acts which may negatively impact water quality. If needed, through provisions of the project or contract, call for work to provide for changed or unanticipated situations. Timeliness is critical.

3. Do not suspend contract time or approve of contractor vacating the project without prevention and control measures being in place.

4. Continuation of work outside the normal operating season shall not proceed withouth a revised Operating Plan which specifically provides for compensating prevention and control measures.

5. As work progresses, monitor measures previously installed to assure their continued effectiveness. Require repair or replacement of those which fail or become damaged immediately. Revise plans, if necessary, to compensate for measures which do not yield intended results.

Followup:

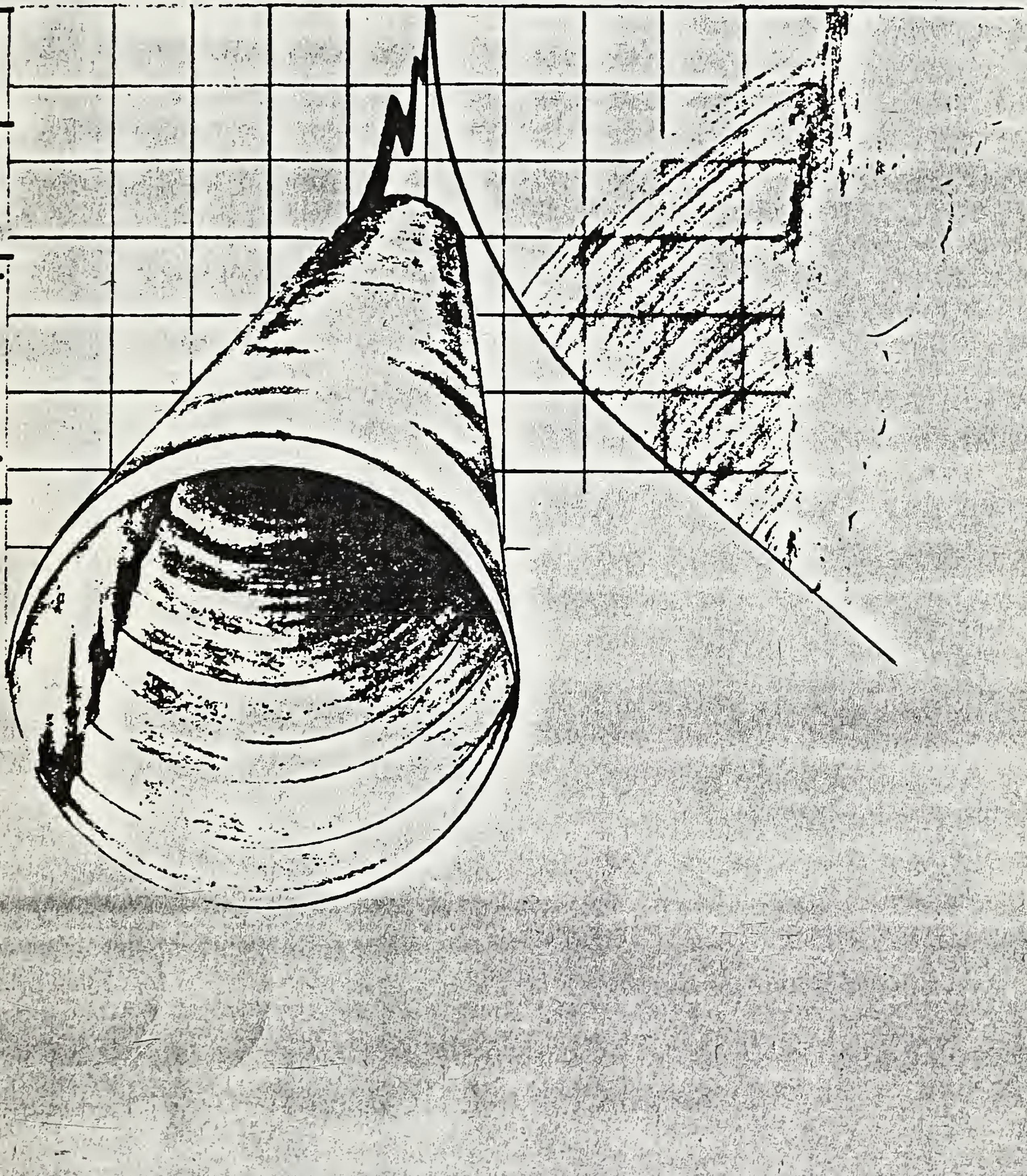
1. At the close of the project, evaluate steps taken to avoid soil loss and water degradation for appropriateness and effectiveness. Make recommendations for improvement, if applicable. Share the results of this evaluation with others involved in project development.

2. Make a field review of the project with the District Roads Manager and other interested parties for purposes of familiarization and continuing the effectiveness of measures taken as the facility moves into operation and maintenance.

7732.02 - Objectives - Lack of response to environmental protection needs in the maintenance of the transportation system is promoted by limited budgets and emphasis on use related activities. Forest direction provides that these needs be treated according to magnitude and severity at a priority level not less than that for keeping facilities functional and available for use. As a minimum, erosion prevention and control shall be addressed co-equally with necessity for providing for user safety and protection of investment.

kootenai national forest

hydraulic guide



KOOTENAI HYDRAULIC GUIDE

BY

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FOREST HYDROLOGIST

WITH CONSULTATION FROM

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MARCH 1977

NEED AND PURPOSE

Accelerated soil erosion is a fundamental problem associated with road design. Perhaps most obvious is the potential loss of productive land. Secondly, the protection of roads and associated structures is an economic concern. Thirdly, downstream water quality and fish habitat may be degraded by an accelerated introduction of sediment into the stream environment. The Environmental Protection Agency identified 90% of accelerated erosion volumes in forested watersheds as originating from roads. 1/ To date, no reliable prediction techniques for Kootenai floods or for culvert spacing exist. A need for basic hydraulics training also exists throughout the Forest.

The purpose of this guide is to present three techniques useful to Forest road designers: Qualitative evaluation of stream response to road encroachments and to stream development; design flow estimation; and maximum cross-drainage spacing guide.

The first section deals with the hydraulic considerations of stream-road situations. This section is discussed first to place emphasis on the need for careful thought in the design of roads and structures that may affect the stability or hydraulics of the streams to be traversed along or across.

To determine the size of structures needed to accomodate the run-off from a drainage basin, peak flows need to be estimated. Section two outlines a method to estimate peak flows for selected return intervals.

Inadequate drainage from a road concentrates water that results in soil loss and resource damage through erosion and mass wasting (land slides). Section three provides a procedure for sp[illegible]g cross-drains so the water is dispersed prior to causing damage.

I. HYDRAULIC CONSIDERATIONS OF STREAM-ROAD SITUATIONS

The objective of this section is to present a qualitative evaluation of river responses to road encroachments and to stream development. The design of complex stream-related engineering problems generally can be facilitated by preliminary qualitative evaluation of hydraulic, hydrologic, and fluvial-geomorphic processes and principles. Quantitative evaluation should follow this qualitative analysis, but is beyond the scope and intent of this guide.

1. Impact Areas

Quantitative evaluations show that location of structures which contact peak stream flows can be conveniently considered to have three impacts; local, upstream, and downstream. The following tables illustrate these impacts. 2/

Case (1) on page 3 involves the construction of a bridge across a tributary stream downstream of where the steeper tributary stream has reached the flood plain of the parent stream. A change in gradient of a tributary stream in most cases causes significant deposition. In general, streams on alluvial fans shift laterally so that the future direction of the approach flow to the culvert or bridge is uncertain.

Case (2) on page 3 illustrates the impact of lower base level for the channel such as with the Kootenai River's flood control dam. The average water surface elevation in the main channel at the time of tributary high flows acts as the base level for the tributary. An increase in tributary gradient increases stream velocities and bank scour. The result is bank instability, changes in geomorphic characteristics of the tributary stream, increased local scour, and delta aggradation.

Design of roads or structures placed near the mouths of the Kootenai River tributaries should consider the effects of the lower base level.

Cases (3 and 4) on pages 4 and 5 illustrate the impacts of channel straightening. Channel gradient increases, causing higher velocities, increased bed material transport, degradation and possible head cutting in the vicinity of the structure. This can result in unstable stream banks and a braided stream pattern.

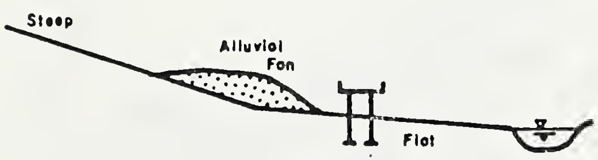
Cases (5-6-7) are self-explanatory. Case (5) on page 6 describes the impacts associated with naturally shifting channels. Cases (6-7) on pages 7 and 8 describes two flood plain situations typical of the Kootenai National Forest; an incised channel and a mature flood plain.

2. Channel Stability

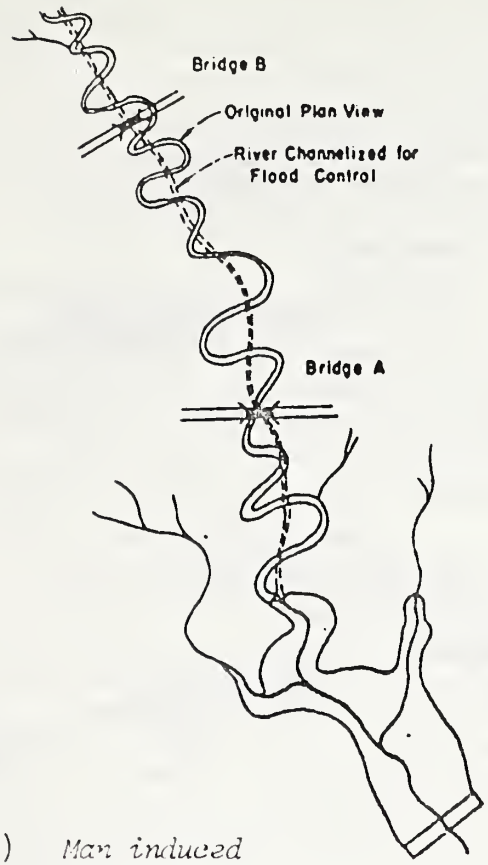
To evaluate the risk involved at any given stream reach, procedures have been developed to systematically measure "the resistive capacity of mountain stream channels to the detachment of bed and bank materials." Risk can be to the structure and/or to the stream itself. This set of procedures is called the "Stream Reach Inventory and Channel Stability Evaluation." 10/

Fifteen items are numerically rated and the ratings summed to yield a total channel stability rating. These total ratings are then grouped into four classes as per the Kootenai National Forest modification: Excellent (<50 pts.), Good (50-75 pts.), Fair (75-100 pts.), and Poor (>100 pts.). These classes exist merely for convenience of discussion because the ratings are a continuum rather than four distinct types.

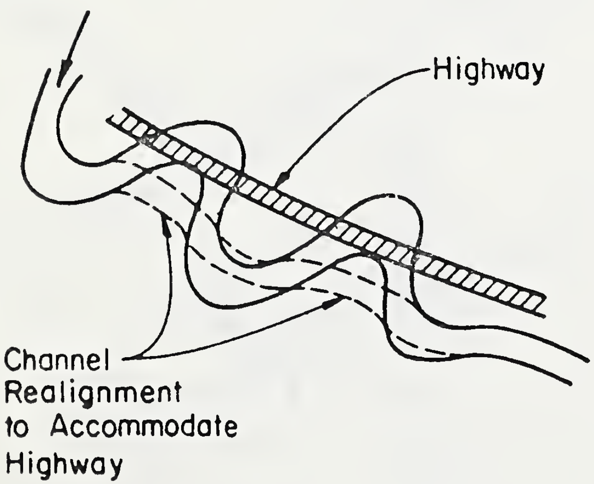
Stream response to road and structure encroachments and to stream development.

Location	Local Effects	Upstream Effects	Downstream Effects
 (1) *Crossing downstream of an alluvial fan*	1 - Fan reduces waterway 2 - Direction of flow at bridge site is uncertain 3 - Channel location is uncertain	1 - Erosion of banks 2 - Unstable channel 3 - Large transport rate	1 - Aggradation 2 - Flooding 3 - Development of tributary bar in the main channel
 (2) *Lowering of base level for the channel*	1 - Headcutting 2 - General scour 3 - Local scour 4 - Bank instability 5 - High velocities	1 - Increased velocity 2 - Increased bed material transport 3 - Unstable channel 4 - Possible change of form of river	1 - Increased transport to main channel 2 - Aggradation 3 - Increased flood stage

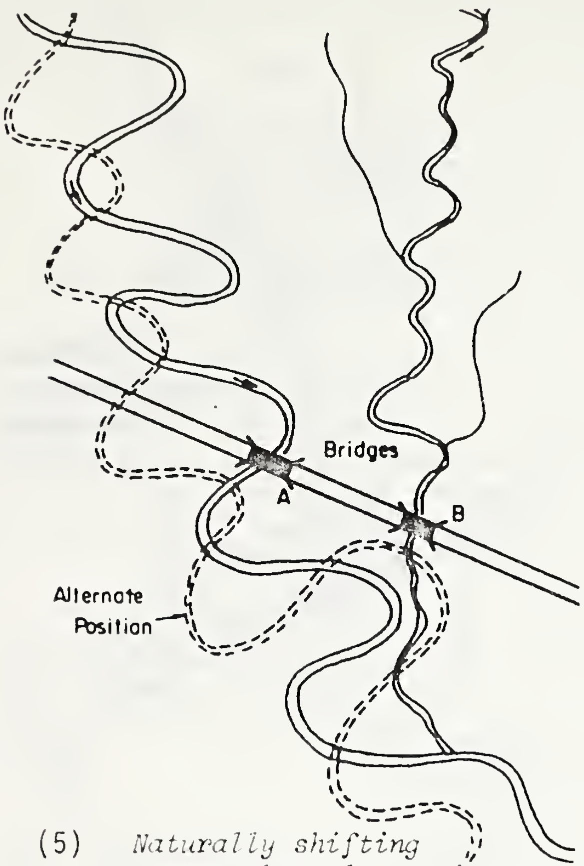
Stream response to road and structure encroachments and to stream development (continued).

Location	Local Effects	Upstream Effects	Downstream Effects
 (3) *Man induced reduction of channel length.*	1 - Bridge A is first subjected to degradation and then aggradation. Action can be very severe 2 - Bridge B is primarily subjected to degradation. The magnitude can be large 3 - The whole system is subjected to passage of sediment waves 4 - River form could change to braided 5 - Flood levels are reduced at B and increased at A 6 - Local and general scour is significantly affected	1 - A change of river form from meandering to braiding is possible 2 - Rate of sediment transport is increased 3 - Head cutting is induced in the whole system upstream of B 4 - Flood stage is reduced 5 - Velocity increases 6 - Tributaries respond to main channel changes	1 - For Bridge B see upstream effects 2 - For Bridge A the channel first degrades and then significantly aggrades 3 - Large quantities of bed material and wash load are carried to the reservoir 4 - Delta forms in the reservoir 5 - Wash load may affect water quality in the entire reservoir 6 - Tributaries respond to main channel changes

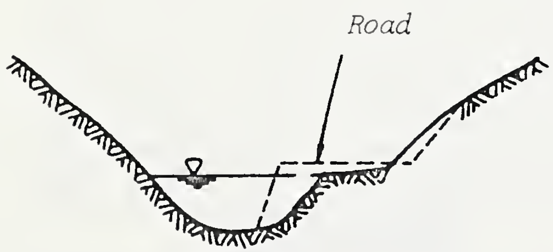
Stream response to road and structure encroachments and to stream development (continued).

Location	Local Effects	Upstream Effects	Downstream Effects
 (4) *Meandering channel Encroaching road*	1 - Increased energy gradient and potential bank and bed scour 2 - Highway fill is subject to scour as channel tends to shift to old alignment. 3 - Reach is subject to bed degradation as headcut develops at the downstream end and travels upstream. 4 - Lateral drainage into the river is interrupted and may cause flooding and erosion.	1 - Energy gradient also increased in the reach upstream and may cause change of river form from meandering to braided 2 - Rate of sediment transport is increased. As the headcut travels upstream severe bank and bed erosion is possible. 3 - If tributaries in the zone of influence exist they will respond to lowering of base level.	1 - Channel will aggrade as the sediment load coming from bed and bank erosion is received. 2 - Channel may deteriorate from meandering to braided.

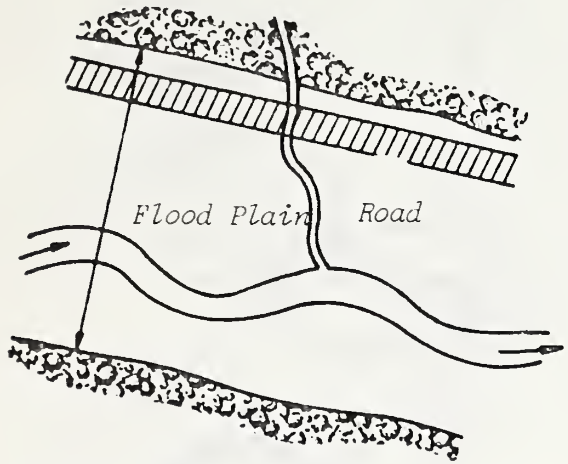
Stream response to road and structure encroachments and to stream development (continued).

Location	Local Effects	Upstream Effects	Downstream Effects
 (5) *Naturally shifting stream channel*	1 - Rivers are dynamic (ever changing) and the rate of change with time should be evaluated as part of the geomorphic and hydraulic analysis 2 - Alignment of main channel continually changes affecting alignment of flow with respect to Bridge A. 3 - If the main channel shifts to the alternate position, the confluence shifts and the tributary gradient is significantly increased causing degradation in the tributary. Local effects on Bridge B same as 1,2,3 and 4 in Case (8). 4 - Excess sediment from the tributary, assuming (3) causes aggradation in the main channel and possible significant changes in channel alignment	1 - The river could abandon its present channel. Changing position of the main channel may require realignment of training works.	1 - See upstream effects 2 - Shifts in the position of the main channel relative to the position of the confluence with the tributary alternatively flattens or steepens the gradient of the tributary causing corresponding aggradation and degradation. 3 - Shifts in the position of the main channel causes aggradation, degradation and instabilities depending upon direction and magnitude of channel change

Stream response to road and structure encroachments and to stream development (continued).

Location	Local Effects	Upstream Effects	Downstream Effects
 (6) *Reduced channel capacity*	1 - Reduced waterway causes a local obstruction to flow and higher velocities. 2 - Significant erosion problem on the highway fill and induced bed degradation 3 - Lateral drainage into the river is interrupted and may cause flooding and erosion.	1 - Backwater generated by the obstruction increases flood stage. 2 - Deposition induced by the backwater	1 - Large sediment load may cause aggradation. 2 - Local scour at end of contracted section

Stream response to road and structure encroachments and to stream development (continued).

Location	Local Effects	Upstream Effects	Downstream Effects
 (7) *Flood plain encroachment*	1 - Erosion of highway fill and submergence possible during floods 2 - Pattern of over-bank spill are affected by the encroachment and in highly shifting channels may change river course downstream. 3 - Lateral drainage into the river is interrupted and may cause flooding and erosion.	1 - If significant encroachment on the floodplain waterway, back-water may be induced.	1 - If the river channel is highly shifting, the channel alignment may change. 2 - If significant erosion experi-enced upstream, aggradation will occur.

In general, channels with excellent ratings are resistant to channel scour and maintain their locations. Channel crossings offer low risk to both the structure and to the stream. They have high capabilities to absorb additional sediment input without negative aquatic life impacts. At the other end of the spectrum, poor streams with poor channel stability ratings often shift channels seasonally or even with each high flow. Constriction of these channels leads to accelerated flows with an associated accelerated channel migration. Proper design in this situation is usually very expensive. These channel types can assimilate a moderate addition of increased sediment loading because the natural stream load is large. Additional loading can be small in comparison to natural.

The channel types most sensitive to sediment loading are the fair to good categories. Degradation of spawning and rearing habitats and water quality indices are significant with only small sediment loadings.

The Forest Hydrologist and the Regional Office - Soil, Air, and Water Section, have explanatory booklets and rating forms for your use. The booklets should be used in the field. Training will be provided by the Forest Hydrologist upon request.

II. PEAK FLOW ESTIMATION

The Forest Service Manual requires that culverts be designed to pass the so-called ten-year flood (10%-chance peak event) without a head at the entrance and the fifty-year (2%-chance) event without exceeding the allowable headwater. Major culverts (End area, greater than 35 square feet) and minor bridges (spans up to, but not exceeding 30 feet) should be designed for the twenty-year peak 5%-chance and checked for the fifty-year peak. All other bridges should be designed to pass a fifty-year peak and checked for a hundred-year peak, 1%-chance. 3/

All structures should be sized and shaped to carry the design discharge economically and should additionally consider:

a. Control or passage of ice and debris.

b. Potential damage due to backwater.

c. Potential damage due to water velocity.

d. Fish passage.

e. Preservation of natural stream banks and bottom for fish habitat and aesthetic purposes.

1. Peak Flow Variables

Peak flow events are a response to a multitude of factors, but due to strong relationships between those factors, critical variables can be identified which can be used to estimate the magnitudes of peak stream flows of selected frequencies. Water inputs on Kootenai streams, as well as with most areas, are best accounted for by drainage area. Concentration time which controls the peak of the stream flow is controlled by land slope and snow melt rates. Melt rates, as well as total water contents available for run-off, are strongly related to elevation exposure, and canopy cover.

On the Kootenai, land slope and elevation are the strongest controls of peak flow per unit area; for flows which occur in the winter. Design flows, such as ten-year return intervals and longer; typically occur during the winter on the Kootenai. Canopy cover moderates the size of these peaks, but does so with less percentage influence as the size of the flow event increases.

The procedure to evaluate design peak flows on the Kootenai National Forest was developed by statistical analysis. This procedure consists of three general steps, each of which is discussed below in detail and an example follows the discussion.

2. Outline of Procedure

2.1. Measure the input variables

- a. Drainage area
- b. Land Slope
- c. Average elevation or headwater elevation

2.2. Calculate the peak flow per square mile for the frequencies required by the F.S.M.

2.3. Calculate the total peak in cubic feet per second.

3. <u>Measurement of Input Variables</u>

3.1. To measure drainage area, outline the topographic divide from the point of interest and measure the area within to the nearest tenth of a square mile. The recommended scale is 1:24,000, but the two-inch and four-inch scales are adequate for most purposes and superior for very large and very small drainages, respectively. Drainages smaller than one square mile or greater than 25 square miles should use an alternative flood estimation procedure. These are given at the end of this section.

3.2. Measure the average land slope by the following procedure. It is important to use this procedure rather than estimates from slope maps because the equation was empirically derived using this procedure.

A. Determine the average slope per sample circle on a map with 40 feet contour intervals.

(1) Overlay the topographic map with the slope determination of the appropriate scales. This plastic overlay is in the envelope at the end of this booklet.

(2) Count and sum the number of contour crossings within each circle for all four lines.

(3) Multiply the total number of contour crossings by 1.19. This yields the tangent of the average land slope of that sample area expressed as a percentage.

B. Calculate the basin average from the samples. One should strive to have a large a sample as possible with a minimum of three samples per square mile; more per unit area may be necessary with smaller drainages. Remember, this doesn't take long, so be time-cost conscious and spend an extra half-hour or so measuring. The precision can be critical.

3.3. Measure the average basin elevation by sampling. Using one of the circles from the plastic overlay and sampling at the same frequency as for the slope determination, observe and record the maximum and minumum elevation within each circle. Then compute the average elevation. This average should be expressed in hundreds of feet to the nearest ten feet. (e.g.; 3973 ft. = 39.7)

3.3a. The ten-year peak uses headwater elevation rather than mean basin elevation. Headwater elevation is observed directly from the topographic map. It is the highest elevation within the drainage, expressed to the nearest one hundred feet. For example, 5000 feet is input to the equation as 50.

4. <u>Calculating Peak Flows</u>

The equations for the design peaks per square mile are:

10-year peak (CSM) = 1.24 - 0.013 (headwater elevation) + 0.846 (average land slope)

20-year peak (CSM) = 41.41 - 1.195 (average elevation) + 1.42 (average land slope)

50-year peak (CSM) = 0.334 + 1.463 (average land slope)

PEAK 00-year peak (CSM) = 64.257 - 1.843 (average elevation) + 2.375 (average land slope)

To determine the peak flow in cubic feet per second (cfs), multiply the peak flows per square mile (csm) times the drainage area in square miles expressed to the nearest tenth of a square mile.

5. Limitations to the Technique

This technique was developed from 12 Kootenai stream records and snow hydrology data from the Kootenai area. As such, it should not be extrapolated beyond the data base from which it is drawn. The limits of this technique are listed below.

Parameter	Minimum	Maximum
Area	1.0 sq. miles	>25 sq. miles refer calculations to Forest Hydrologist
Ave. Elevation	3200 feet	6000
Ave. Land Slope	4 percent	60 percent
Ave. Ann. Precip.	27 inches	78 inches

Soil/Geology - Not applicable to calcareous, deep, permeable materials.

6. Small Drainages

For drainages less than 640 acres in size, the above technique under-estimates peak flows. Several techniques exist which give estimates for small drainages and for low precipitation/droughty soil conditions. All three techniques should be used where possible to check against each other.

6.1. Historical Method: Perhaps the best method is to field check "existing" culverts to see if they held through the 1974 and 1975 peaks. For streams along the Bull River/Lake Creek "Valley", the 1972 event should be used, because the 1972 event was about three times larger than the 1974 event there.

This technique is often infeasible because "new" areas are being developed. Field observation can still be used. For example, recent research demonstrates that geomorphic interpretation is superior to soil, vegetation, or calculated values (from runoff) for estimating channel capacities. Design of pipes to channel capacities can lead to over-estimates where the stream has migrated laterally. This error is not as bad effectively as it may appear because channels subject to migration need more pipe capacity to mitigate against migration.

6.2. Manning's Equation

Coupled with field measurements of the channel, Manning's equations can be used. Recommended "n" values range from 0.04 to 0.06. This includes the range of natural channel roughness values normally encountered at peak flow in mountainous streams; ranging from slick, grassy conditions to rough, bouldery conditions.

Manning's equation is $v = \frac{1.49}{n} R^{2/3} S^{1/2}$

Converting to solve for cubic feet per second (Q) the formula becomes:

$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$ or area times velocity

where

Q = discharge in cubic feet per second.

n = roughness coefficient (0.04 to 0.06)

A = Cross-sectional area of channel

R = hydraulic radius (ft.) = $\frac{A}{P}$

P = wetted perimeter (ft.)

S = channel slope (ft./ft.)

6.3. Rational Formula

A third technique is the so-called "rational" formula:

$$Qp = C\ i\ a$$

where

- Qp is a peak flow in cfs for a given frequency of rainfall intensity.
- C is a constant between 0 and 1 which is supposed to represent watershed conditions.
- i is the rainfall rate in inches per hour (for the design frequency).
- a is the area in acres.

Using E.L.U. maps, the C values an be estimated from the description and table given.

SUBSTRATUM (least permeable horizon) "C" Value	Full Canopy	Clear-Cut
Calcareous	0.30	0.52
Non-Calcareous		
Course-textured	0.40	0.62
Medium-textured	0.50	0.72
Fine-textured	0.60	0.82

> 30% [illegible]

7. Large Drainages

Several methods exist for estimating peak flows from large drainages, including: U.S. Geological Survey's Water Supply Paper 1687, Boner and Omang (1967), Soil Conservation Service (1971), and Dodge (1974). Flood estimates from large basins should be referred to the Forest Hydrologist.

The information and tools the Forest Hydrologist will request from you include:

1. Topographic map of drainage basin with watershed delineated. This map should have a scale no smaller than 1:62,500.
2. Existing and proposed Forest canopy within drainage.

3. Computed mean stream gradient between 10% and 85% points along main channel length. Channel length is extended tnrougn contour notches up to the watershed divide.

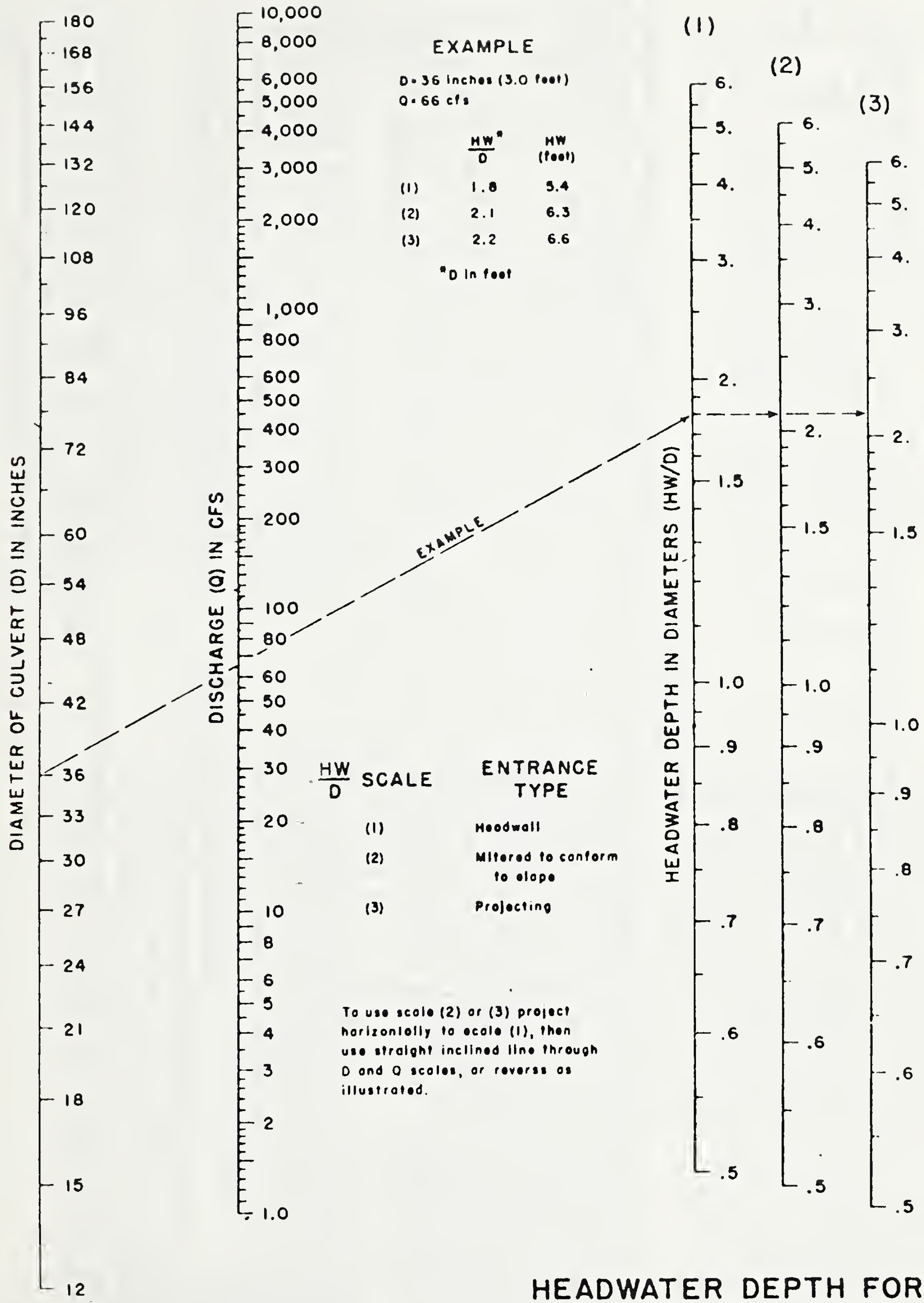
4. Percent land area in lakes and ponds plus one percent (for streams) within the drainage basin.

5. Channel stability rating of channel at point of proposed crossing.

8. <u>Culvert Sizing</u>

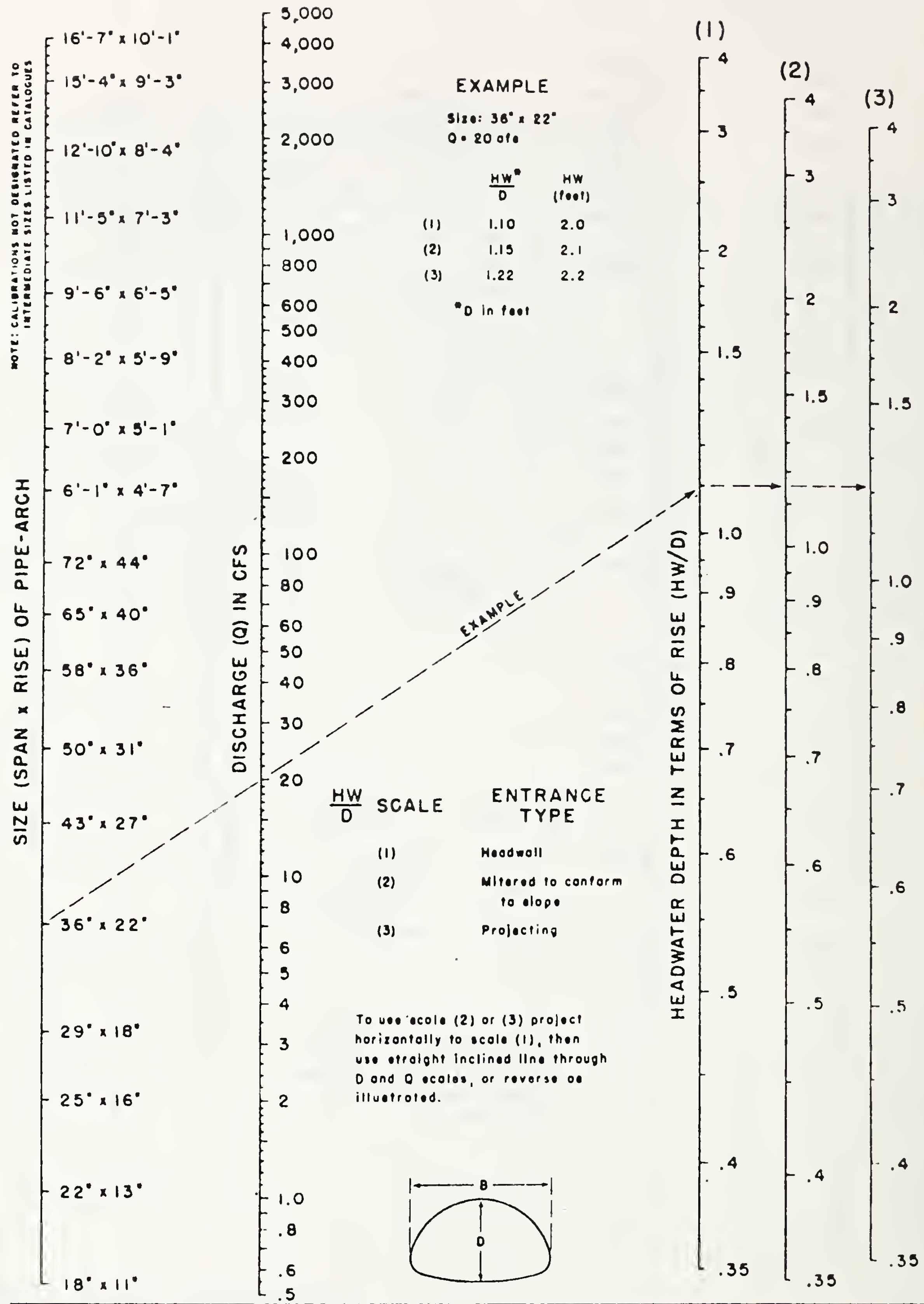
Referring to the nomograms for either circular C.M. pipe culverts (page 15)or C.M. pipe-arch culverts (page 16) depending on which is more appropriate and following the directions thereon the pipe size can be determined. Both nomograms are for inlet control, the most usual case on the Forest. For other conditions refer to the appropriate reference. 3/

Effort should be made to fit culverts and similar structures to the channel geometry. This means stream gradients and curvatures should be maintained to maintain the dynamic equilibrium reached by the stream and its geomorphic expression. The consequence of not maintaining the gradient may be hydraulic disequilibrium and associated scour and/or depostion, thus risk of the fish habitat, water quality, the structure, and aesthetics.



BUREAU OF PUBLIC ROADS
OCTOBER 1960

HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL



HEADWATER DEPTH FOR C. M. PIPE-ARCH CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS
OCTOBER 1960

III. CROSS-DRAINAGE SPACING

The objective of road drainage is to disperse the water in order to minimize the risk of erosion and the saturation of fill slopes. Similar to stream crossings and for similar reasons culverts should fit the terrain. This means all draws should have culverts. As a check against this spacing a maximum spacing guide is presented. Where the terrain for one reason or another has natural drainage lines spaced more widely than the spacing guide ditch-line relief should be installed.

Culverts in draws, flowing at least seasonally, should have a minimum 24" diameter. The minimum size is designed to allow for the possibility of partial blocking by debris and to minimize the possibility of ponding and high water velocities. Where the design flow suggests a larger pipe than 24" or a debris problem is present, the pipe should be appropriately larger. Where fish habitat exists a fish biologist and/or hydrologist should be consulted.

Ditch-relief may be an open-top design, drainage dips, or C.M.C. If C.M.C., the minimum size should be 18". In the drier, less erodible situations with gentle road gradients out-sloping of the road is often superior because this will disperse the water, is less expensive to build, and requires less maintenance.

The maximum spacing guide is most important and useful in those wet sites with little or no natural drainage lines. Road cuts concentrate subsurface water on the surface, thus creating the potential for surface erosion where the water concentrates.

The maximum spacing guide is developed from ...nai observations and checked against guides developed elsewhere. It considers these critical factors: site moisture content, soil material, road grade, and slope position. Habitat types based on Pfister's classification for western Montana, 7/ and land types, a soils-geomorphic mapping system developed by Kuennen and Galbraith for the Kootenai National Forest 8/ identify soil moisture situations which commonly exist during "spring-breakup". The land types also identify the erodibility of the soil materials. In combination the force (water flow) and resistance (soil material) are identified by Ecological Land Units (ELU), a system of mapping units of habitat type/land type combinations.

The ELU's have been evaluated for their soil erodibility into ten classes; class one being least erodible and class ten being most susceptible to erosion. Importance is placed on the resultant rather than focusing upon either the soil material or the moisture condition. Important exceptions are shallow soils in high water yield sites which are not erodible. Dispersing the water from the roads in this site is important due to downslope consequences of concentrated flow.

Steeper road grades increase water velocities and volumes thus necessitating more cross-drainage. The graphical solutions found on pages 20-21, relates moisture, soil material, and road grade to a recommended maximum spacing of cross-drainage.

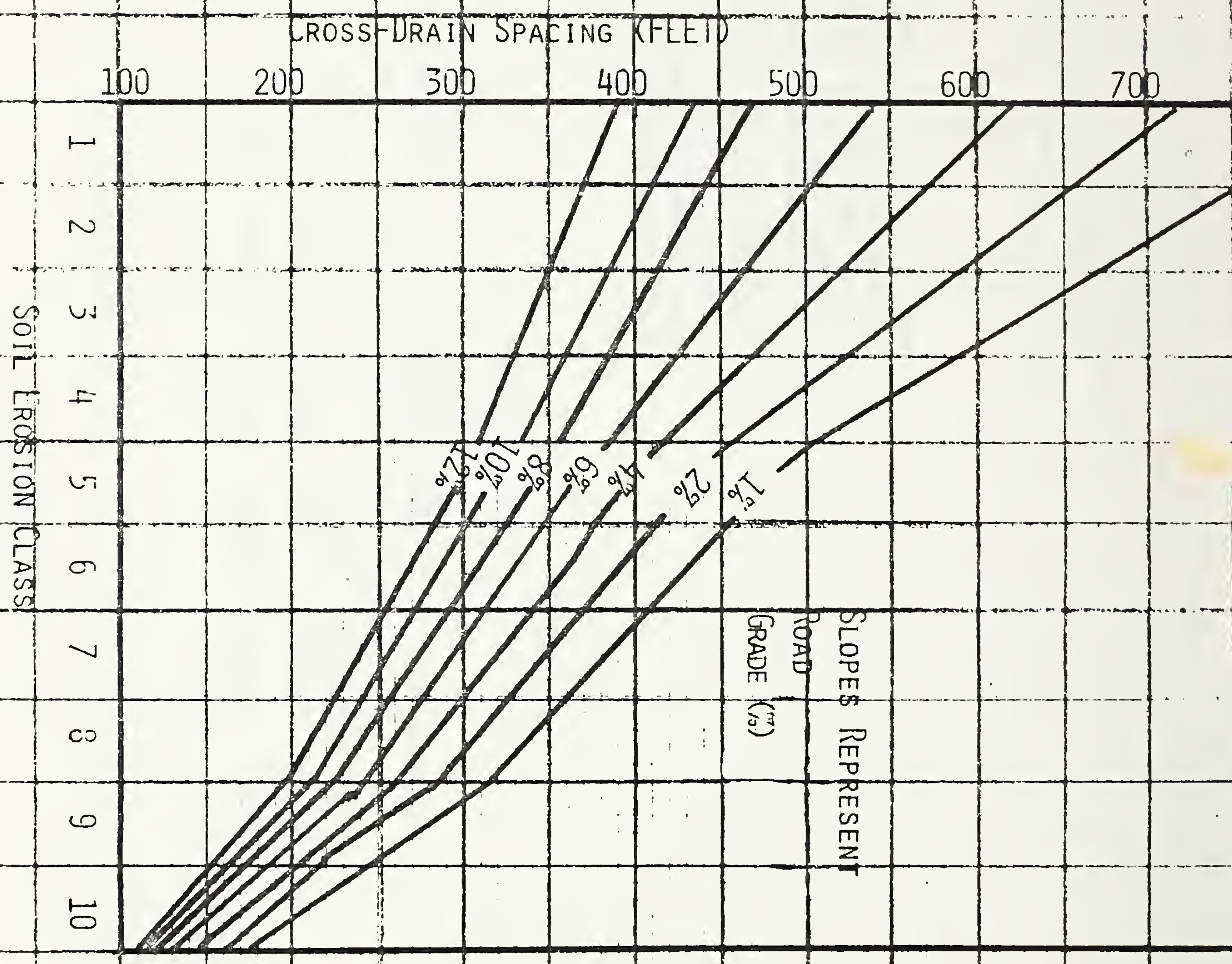
To read the graph identify the ELU from District maps and find the proper soil erodibility class for that ELU on page 19. Referring to the appropriate graph, project vertically to the appropriate road grade and then project horizontally to the maximum spacing.

Fu..ier modification of this is often necessary due to slope position. Lower slope positions, although usually drier prior to road construction can become overloaded with water, where roads are stacked on top of each other up a slope. Shortening of the spacing identified in the chart is necessary in this case.

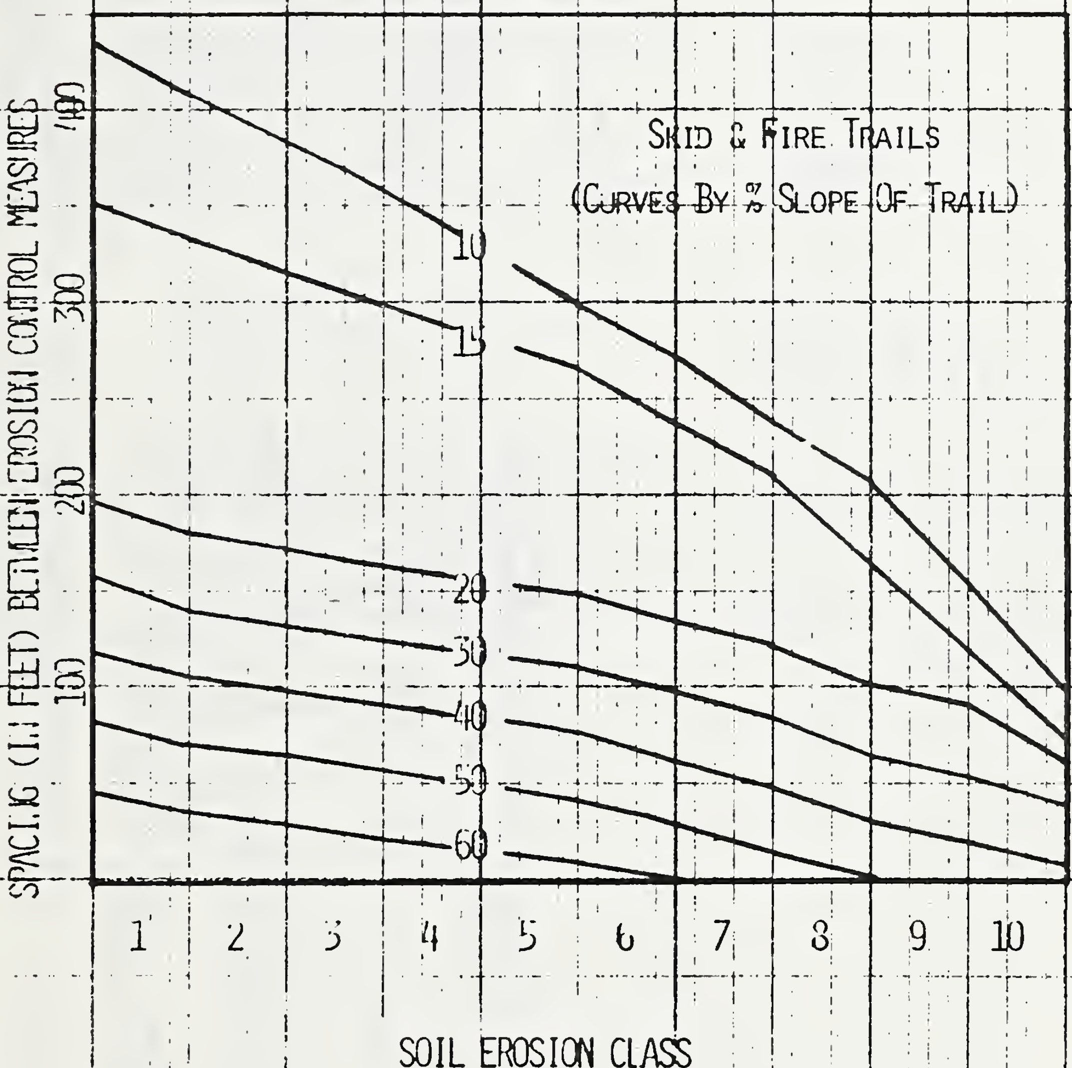
A drainage plan should be prepared for all slopes with multiple roads. This is a contour map showing the flow of water in the area and how that flow is affected by the roads and drainage structures. The drainage plan will aid the designer in locating structures so water will not be concentrated into areas that may be saturated and cause heavy erosion or mass failure, or overload a channel beyond its capacity. All existing and planned roads should be considered when preparing a drainage plan.

SOIL EROSION CLASS 9/

	1	2	3	4	5	6	7	8	9	10
	1-10	31-35	36- 41	76- 80	66- 70	16	17- 20	21- 25	307-312	186-193
		46-50	51- 55	96-101	81- 85	141-146	121-125	126-131		
E.			61- 65	166-170	136-140	148	216-220	231-234		
L.			91- 95	241-252	147	156-162	227-230			
U.			102	271-275	151-155	221-223				
			256-260		171-178	226				
					201-208					
					286-291					



Cross-Drain Spacing (Feet)
100
200
300
400
500
600
700
Soil Erosion Class
1
2
3
4
5
6
7
8
9
10
12%
10%
8%
6%
4%
2%
1%
Slopes Represent
Road
Grade (%)



SKID & FIRE TRAILS
(CURVES BY % SLOPE OF TRAIL)
10
15
20
30
40
50
60
SPACING (IN FEET) BETWEEN EROSION CONTROL MEASURES
100
200
300
400
1
2
3
4
5
6
7
8
9
10
SOIL EROSION CLASS

REFERENCES

1/ Environmental Protection Agency (1975): Logging Roads and Protection of Water Quality

2/ Federal Highway Administration (U.S. Department of Transportation) (1975): Highways in the River Environment; Hydraulic and Environmental Design Consideration, Training and Design Manual. Chapter VIII.

3/ Forest Service Manual: 7720 Interim Directive No. 1 (August 24, 1976).

4/ Wentworth, C.K. (1930): A Simplified Method of Determining the Average Slope of Land Surfaces, American Journal of Science, Series 5, Vol. 20, pp. 184-194.

5/ Developed by Tolle, 1976 from 12 Kootenai N.F. stream records reported by U.S. Geological Survey

6/ Bureau of Public Roads (1961): Hydraulic Engineering Circular No. 5.

7/ Pfister, Robert, Bernard Kovalchik, Stephen Arno, and Richard Presby (1974): Forest Habitat Types of Montana.

8/ Kuennen, Louis J. and Alan Galbraith (1971): Unpublished land type classification for the Kootenai N.F.

9/ Developed by Kuennen, L.J., L. Collett, and T.V. Tolle (1976).

10/ Pfankuch, Dale (1975): Stream Roach Inventory and Channel Stability Evaluation; R1 Watershed Management Procedure.

ELU #'s	General Description	Land types
1-10	Stream Terraces and Bottoms	101,103,105,106,111
31-35	Hummocky Valley Terrain	104,321,322,324
46-50	Oversteepened	201,202,251,401,402,403
36-41	Hummocky Valley Terrain	104,321,322
51-55	Oversteepened	210,202,251,401,402,403
61-65	Scarp Slopes	252,253,551
91-95	Ice Scoured	303,304,305,360,
102	Ice Scoured	303,304,305,360
256-260		
76-80	Deep Glacial Tills-South Aspect	301,302
96-101	Ice Scoured	303,304,305,360
166-170	Mod. Shallow Alpine Glacial Till	354,408
241-252	Deeply Weathered Limestone	325
271-275		
66-70	Scarp Slopes	252,253,551
81-85	Deep Glacial Tills-South Aspect	301,302
136-140	Deep Glacial Tills	352,357,404
147	Deep Glacial Till	352,357,404
151-155	Shallow Soils	353,355,356,359,372
171-178	Mod. Shallow Alpine Glacial Till	354,408
201-208	Alpine Forest Churned	405,406
286-291		
16		
141-146	Deep Glacial Tills	352,357,404
148	Deep Glacial Tills	323,352,357,404
156-162	Shallow Soils	353,355,356,359,372
221-223	Valley Glacial Till	364,407
226		
17-20	Lacustrine Benches & Terraces	102
121-125	Compacted Glacial Till	351,351A,365,366,381,451
216-220	Valley Glacial Till	364,407
227-230		
21-25	Lacustrine Benches & Terraces	102
126-131	Compacted Glacial Till	351,351A,365,381,451,366
231-234		
307-312		
186-193	Decomposed Granitics	370,371

UNIT #	PARENT MATERIAL Surface/Subsoil	U.S.C. Surf./Subsoil	P.I. Surf./Subsoil
101	Recent alluvium	SM/GP	0-5/NP
101w	Poorly drained alluvium	ML/SM	5-10/NP
102	Loess/Silty lake sediments	ML/ML	5-10/5-10
103	Loess/Well drained alluvium	ML/GP	0-5/NP
104	Loess/Glacial drift	ML/GM	0-5/5-10
106	Loess/Glacial outwash	ML/GW	NP/NP
108	Loess/Lacustrine alluvium	ML/SM-GP	0-5/0-5
110	Outwash sand	SM	NP
112	Loess/Clayey lake sediments	ML/CL	0-5/10-15
201	Residual Belt rock	GM/GW-GM	NP/NP
251	Loess/Residual Belt rock	ML/GW-GM	0-5/NP
252	Loess/Residual Belt rock	ML/GM	0-5/NP
301	Glacial till	ML/SM	0-5/0-5
302	Glacial till	ML/SM-GM	0-5/0-5
303	Scoured bedrock	SM/GM	NP/NP
321	Glacial till	ML/GM	0-5/0-5
322	Loess/Silty glacial till	ML/ML	0-5/5-15
323	Silty glacial till	ML/SM-ML	5-10/10-15
324	Calcareous glacial till	ML/GM	0-5/0-5
325	Calcareous glacial till	ML/SM-ML	5-10/10-15
328	Loess/Calcareous glacial till	ML/GM	0-5/NP
329 to	Loess/Glacial till	ML/GM	0-5/NP
357	(units vary with slight gradation differences in subsoil)		
360	Loess/Scoured bedrock	ML/GM	0-5/NP
365	Loess/Glacial till	ML/GM	0-5/NP
370	Loess/Granitic soils	ML/GP-GM	5-10/NP
381	Loess/Continental tills	ML/GM	5-10/NP
401	Loess/Residual soils	ML/GM	5-10/NP
403	Loess/Residual soils	ML/GM	5-10/NP
404	Loess/Alpine till	ML/GM	5-10/NP
405	Loess/Residual soils	ML/GM	4-10/NP
406 to	Loess/Alpine till	ML/GM	5-10/NP
408	(units vary with slight gradation differences in subsoil)		
502	Belt residual soils	SM/GM	NP/NP
503	Belt residual soils	SM/GM-GW	NP/NP
510	Belt residual soils	GM/GM	NP/NP
520	Loess/Pyroxenite	ML/GM-ML	5-10/NP
522	Loess/Metadiorite tills	ML/GM	5-10/NP
552	Loess/Residual Belt soils	ML/GM	5-10/NP
555	Loess/Residual Belt soils	ML/GW-GM	0-5/NP
570	Loess/Granitic soils	ML-SM/GP	NP/NP

Geotech/Materials Workshop –1984

Erosion Control for Road Design

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DEPARTMENT OF AGRICULTURE